Vol. LXXXVI. No. 4. July–August, 1949

GEOLOGICAL MAGAZINE

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STEPHEN AUSTIN & SONS, LTD.
1 FORE STREET, HERTFORD, HERTS

SUBSCRIPTION 30/- PER ANNUM

GEOLOGICAL MAGAZINE

founded in 1864

by the late Dr. H. Woodward, F.R.S., with which

is incorporated

THE GEOLOGIST

(founded 1858)

Published every two months, price 30/- per annum
(single numbers, 6/-).

Subscriptions for 1949, inquiries relating to back stock, advertising, etc., should be sent to Stephen Austin & Sons, Ltd., Fore Street, Hertford, Herts.

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GEOLOGICAL MAGAZINE

VOL. LXXXVI. No. 4. JULY–AUGUST, 1949

The Yorkshire Dogger

IV. ROSEDALE AND FARNDALE

By R. H. RASTALL and J. E. HEMINGWAY

ABSTRACT

The Lias-Oolite junction in Rosedale and Farndale is defined. The underlying Lias is folded into a pre-Oolite complex of shallow Caledonoid folds, wherein are preserved about 55 square miles of Yeovilian strata in the Cleveland region. The Rosedale East and Sheriff's Pit ironstones, now exhausted, are included on field evidence with the Yeovilian and not the Dogger. They occur in the troughs of two structural basins of limited extent in the fold complex, while other basins hold ironstones of no economic value. It is unlikely that the depositional basin of the Rosedale ironstones extended far beyond the present limits of the dale. Within Rosedale its distribution was materially reduced by erosion from the crests of minor pre-Dogger folds, pebbles now phosphatised derived from the crests occurring in the base of the Dogger.

A three-fold sub-division of the Dogger is recognized. The Glaisdale Oolite is here of little importance ; the lenticular Rosedale Sandstone represents sand trapped in the continued down-warping over Rosedale in early Dogger times. The most widely spread rock group, the Blakey Series, includes the important Black Shales at its base. Marked facies variation is recognized in the sandy upper part, which includes the Ajalon facies, the Green Flag facies, etc., which were earlier incorrectly regarded as in chronological succession.

The Rosedale magnetite-oolite is regarded as a sedimentary deposit underlying the Dogger.

The petrography of the several beds of the Lias-Oolite junction is briefly described.

THE fertile valleys of Rosedale and Farndale, draining south off the Cleveland dome, expose the Lias-Oolite junction at the break in slope controlled by the heather-covered Deltaic Series [1] of the moors above and the Lias of the valley sides and floors. In many respects these exposures mirror those of the dales in the northern flank of the Cleveland dome already described (Rastall and Hemingway, 1943). Farndale reflects Westerdale and Danbydale in the relative simplicity of the Lias–Oolite junction, whereas Rosedale even exceeds the complexity of the Fryups.

Earlier descriptions of the Dogger of this region are few. In view of

[1] For the revised terminology of the Middle Jurassic of Yorkshire, see Hemingway, 1949.

the active exploitation of the ironstones at or near this horizon at the time of the survey it is notable that the Geological Survey sheet memoir (Fox-Strangways, Reid, and Barrow, 1885) is inadequate and at times incomprehensible. The later Survey report (Lamplugh in Lamplugh, Wedd, and Pringle, 1920) added little to this field account, but confused it by an indefinite and sometimes incorrect topography.[1] These official Survey records have recently been reprinted with slight additions (Anderson, 1942). Of the several field accounts of the magnetite-oolite, some of which are largely speculative, that by Marley is the most factual (Marley, 1869–70). More recently the petrography of some of these rocks has been described (Hallimond, 1925).

In the stratigraphical field Macmillan has demonstrated the presence of Yeovilian rocks in this area (Macmillan, 1932). In view of this work on the faunal subdivision of the Yeovilian, which is not yet complete, we have directed our attention mainly to the overlying beds, as we have already indicated (Rastall and Hemingway, 1943, p. 209). Reference is made to the Yeovilian in so far as it provides a necessary introduction to the sedimentary conditions controlling Dogger deposition and also with reference to the age and petrology of the Rosedale East and other ironstones, hitherto regarded as of Dogger age. Although not concerned with the zoning of the Yeovilian, we have determined its upper limit, from which the Inferior Oolite has not previously been differentiated.

In an earlier paper (Rastall and Hemingway, 1943) we divided the Dogger of Upper Eskdale into three series, subdivided as follows :—

Ajalon Series . .	Black Oolite Ajalon Oolite and Sandstone Woodhead Scar Sandstone
Chamosite Series . .	Finkel House Group Danby Group < Green Flags / Black Shale
Glaisdale Oolite Series .	Glaisdale Oolite

This classification now requires modification. As is shown later the evidence in Rosedale suggests that the Green Flags of the Danby Group and the Woodhead Scar Sandstone are only facies variants of the main Dogger sandstone, here named for convenience the Blakey Series. The terms will therefore be used only in facies terminology. The age of the coarser sandstones and the sandy oolites

[1] In the map, Fig. 7 on p. 29 of this memoir, Sheriff's Pit is displaced 1½ miles south-east of its real position.

of the Ajalon facies is here unproven. Field evidence is not conclusive, and future exposures may well prove them to be the coarsest facies of the Blakey Series, which opinion the writers now hold. The Finkel House group of oolites and chamositic rocks, known in Eskdale in but two small areas, is unrepresented in the southern dales. From the evidence in Rosedale these also may be facies variants of the Blakey Series. A green sandstone not found in Eskdale occurs widely in Rosedale below the Black Shales, where it is a valuable horizon marker ; it may be named for convenience the Rosedale Sandstone. Only the Glaisdale Oolite is unrelated in Rosedale to the remainder of the Dogger sequence, but from evidence in Great Fryup it is placed below the Danby Group (Rastall and Hemingway, 1943).

The Dogger succession in Rosedale, which is also a revision of the succession of the dales to the north, is therefore as follows :—

Blakey Series . .	Black Oolite, Ajalon facies, Woodhead Scar facies, Green Flag facies, etc.
	Black Shales
Rosedale Sandstone .	A chamositic sandstone
Glaisdale Oolite .	

An outstanding feature of the rocks of the Lias-Oolite junction of Rosedale is the extensive development of oolitic ironstones which, with the exception of the magnetite-oolite, are all low grade. It is notable that this development is not confined to one horizon but occurs, though in varying degrees, in both the high Yeovilian and Inferior Oolite. It is the association and part superposition of two ferruginous rock groups at different horizons and under different geological controls, which has caused past confusion on the position of the Lias-Oolite junction in this region.

These ironstones have in the past been worked at the following mines :—

Rosedale East Mines, which have a worked-out area of about 550 acres, and which yielded chiefly a chamosite-oolite with 32·7 per cent metallic iron in the raw stone and 45·6 per cent iron in the calcined state (Fox-Strangways, etc., 1885). This latter figure is open to doubt, since it is identical with that of the iron content of calcined magnetic ironstone from these mines.

Rosedale Magnetite Mines, worked in medieval times, but which yielded over 3,000,000 tons of magnetite-oolite between 1857 and 1880 from two deposits each 5 to 6 acres in extent. The ironstone

contained 42·96 per cent metallic iron in the raw stone and 52 per cent in the calcined state.

Sheriff's Pit, a much smaller concern, working a chamosite-oolite with 36·6 per cent metallic iron in the raw stone (Fox-Strangways, etc., 1885).

Within Rosedale the multiplicity of abandoned ironstone workings and trial holes in the Dogger and subjacent beds increases rather than diminishes the difficulty of determining the nature of the Lias-Oolite junction. The adits are in all cases collapsed, and exposures in their vicinity obscured by debris. Unfortunately, this is particularly true of the Rosedale Magnetite Mines, where the collapse of the underground workings has formed a considerable syncline in the overlying beds. As a result the magnetite-oolite is nowhere exposed, and its field relations cannot now be directly determined.

Mention may also be made of the many landslips, some exceeding half a mile in length, which festoon the sides of the dales and too frequently hide critical horizons. Their presence did much to control nineteenth-century exploration for ironstone.

Apart from the unusual and in some cases unique developments of oolitic ironstone, the several members of the Yeovilian and the Dogger occur in Rosedale and Farndale, with little fundamental change in lithology from that described further north (Rastall and Hemingway, 1943). Further, the faunal content of the Dogger is no less sparse and no more diagnostic than in the northern outcrops. There is no need, therefore, to describe in detail the various members of the Lias-Oolite junction, but rather to consider immediately their inter-relation within the limits imposed by the lack of outcrops.

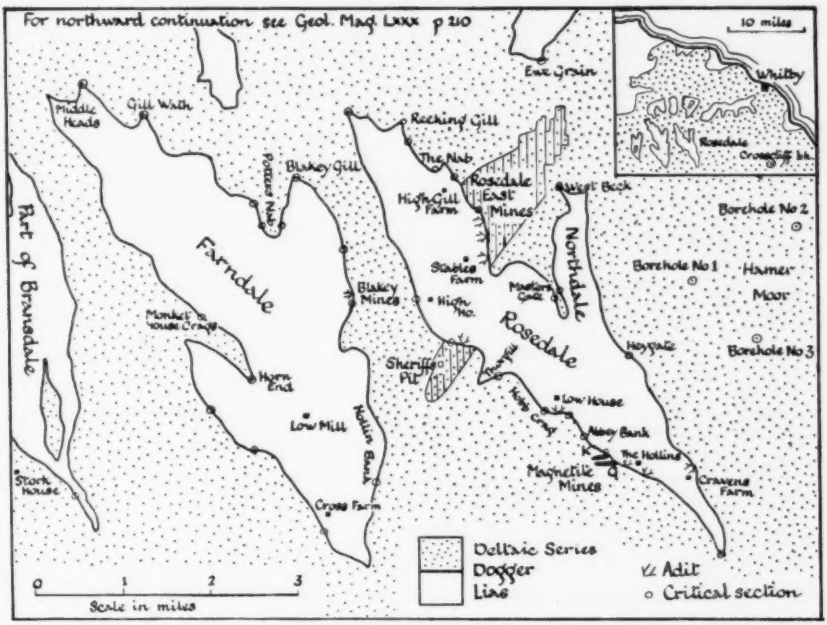
Field Relationships

Rosedale

At the north end of Rosedale the Lias-Oolite junction is typical of many of the western Cleveland valleys, and can be seen in Reeking Gill, in the shale gorge near the head of the River Seven, and in adjacent gullies. A generalized section at the dale head shows :—

	ft.	*in.*
Dogger—		
Blakey Series—		
Green Flags facies	4	0
Black Shale	6	0
Yeovilian—		
Siderite mudstone with chamosite ooliths, richly fossiliferous in places		9
Serpula Series—		
Serpula Sandstone	6	0
Striatulum clays	10	0

From the siderite mudstone a fauna including *Trigonia literata*, *Echinotis substriata* and species of *Cucullea* and *Gresslya* has been collected. These are long-range forms and of no diagnostic value, but the similarity of the lithological characters, field relations, and faunal assemblage of this bed to that at Double Dikes, Fryup (Rastall and Hemingway, 1943, p. 211), suggests its Yeovilian (*dispansum*) age. From the underlying Serpula Series, Macmillan has recorded ammonites



TEXT-FIG. 1.—Locality map of Rosedale, Farndale, and part of Bransdale, showing the underground extent of the ironstone mines (vertical ruling). Of the two magnetite mines (in black) K indicates Kitching's Deposit and G Garbutt's Deposit.

which place these beds in the *striatulum* zone (Macmillan, 1932), and which demonstrate a facies variation within this zone.

From Reeking Gill the Oolite-Lias junction may be traced southwards along the eastern side of the dale (Text-fig. 2). In this direction the thin Yeovilian siderite-mudstone thickens to some 6 feet of poor ironstones, pebbly throughout, while immediately below the Deltaic Series, the Green Flags facies pass into a more thickly bedded variant. Further, the Rosedale Sandstone appears between the Danby Group and the Yeovilian. Thus, in the disused railway cutting at the

Nab, 1,100 yards south-east of Reeking Gill, a complete section shows :—

	ft.	*in.*	*ft.*	*in.*
Lower Deltaic Series—				
Clay with thin coal			15	0
Soft feldspathic sandstone			5	0
Dogger—				
Blakey Series—				
Greenish sandstone in 9 in. beds			10	0
Green Flags facies			1	6
Black Shales			5	6
Scattered pebbles				
Rosedale Sandstone—				
Greenish sandstone			1	4
Yeovilian—				
Rosedale East Ironstone—				
Fossiliferous pebble bed				6
Dense siderite-mudstone with belemnite casts	1	6		
Oolitic siderite-mudstone	1	0		
Softer well bedded oolitic ironstone	3	1	6	4
Variably oolitic siderite-mudstones crowded with *Oxytoma inaequivalvis* (J. Sow.)		9		
Serpula Sandstone			5	0
Striatulum Clays			15	0

The next critical section lies 750 yards to the south-east and 300 yards E.S.E. of High Gill. Here the Rosedale Sandstone lies directly on the Serpula Sandstone and Rosedale East ironstone is cut out, though mine plans show that it was worked a short distance to the east. The Green Flag facies is replaced by a coarser variant approaching Woodhead Scar facies. The complete section is :—

	ft.	*in.*
Dogger—		
Blakey Series—		
Brown sandstone in subsoil		—
Black silty shale	3	0
Rosedale Sandstone—		
Green sandstone with ooliths	3	0
Yeovilian—		
Serpula Series—		
Micaceous sandstone with fine vertical worm tubes near top : lower half crowded with massed serpulae	7	0
Row of purplish oolitic siderite-mudstone nodules		—
Softer silty sandstone	6	0
Harder serpula sandstone	1	0
Scree		

It is suggested that here the developing Rosedale East Ironstone was eroded from the crest of a rising N.E.–S.W. anticline at the end of Yeovilian times and the Dogger was subsequently laid unconformably across its truncated edges. In width this fold is only small, since to the south the ironstone again appears and soon attains sufficient thickness

to have been worked. But its control upon an ironstone once economically valuable is seen in the north-west boundary of the worked-out ironstone area which passes in an almost straight line through this outcrop (Text-fig. 1).

Behind Black Houses, 300 yards south-east of the previous section, the ironstone again appears between the Serpula and Rosedale Sandstones. This agrees with the mining records to the north-east, where the ironstone is " less than three feet thick and poor in quality " (Lamplugh, 1920, p. 30). South of this point for about 600 yards the collapsed adits and ruined buildings mark the site of Rosedale East Mines. Here the upper part of the Dogger may be traced almost continuously, as can the Serpula Series below, but the ironstone is usually hidden under scree. A typical section 300 yards east of Stables Farm shows :—

	ft.	*in.*
Lower Deltaic Series—		
Grey clays		
Dogger—		
Blakey Series—		
Khaki sandstone, oolitic and coarser near top, sandy and fine-grained below. Occasional lenses of siderite-mudstone up to 3 inches thick	10	0
Black shales with fine sandy lenses	4	10
Rosedale Sandstone—		
Greenish sandstone with ooliths. Scattered pebbles	2	0
Yeovilian—		
Rosedale East Ironstone	*seen*	
Hidden	about 6	0
Serpula Series—		
Typical sandstone with worm tubes and some silts	15	0

The upper part of the sandstone has yielded *Hudlestonia affinis* Seebach and *Phlyseogrammoceras* sp. confirming its *dispansum* age.

The ironstone has yielded a small fauna as follows, which should not be considered representative because of lack of exposures.

Gresslya abducta (Phillips)
Isocyprina sp. (conceivably " *Cardium* " *gibberulum* Phillips).
Ostrea (*Lopha*) sp.
Trigonia denticulata (Agassiz).
Trigonia spinulosa (Young and Bird).
" *Terebratula* " *trilineata* (Young and Bird).

No ammonites were found, nor have they previously been recorded from the ironstone.

In the central part of the mine the ironstone was generally 7 feet thick, from which it diminished in all directions (Lamplugh, 1920, p. 30). A maximum thickness of 14 feet was also claimed (Fox-Strangways, etc., 1885, p. 26). It is also recorded that " for a short distance there is a seam of magnetic stone about 14 inches thick, containing *Pecten demissus*, Phil. . . . It formed a lenticular mass in the

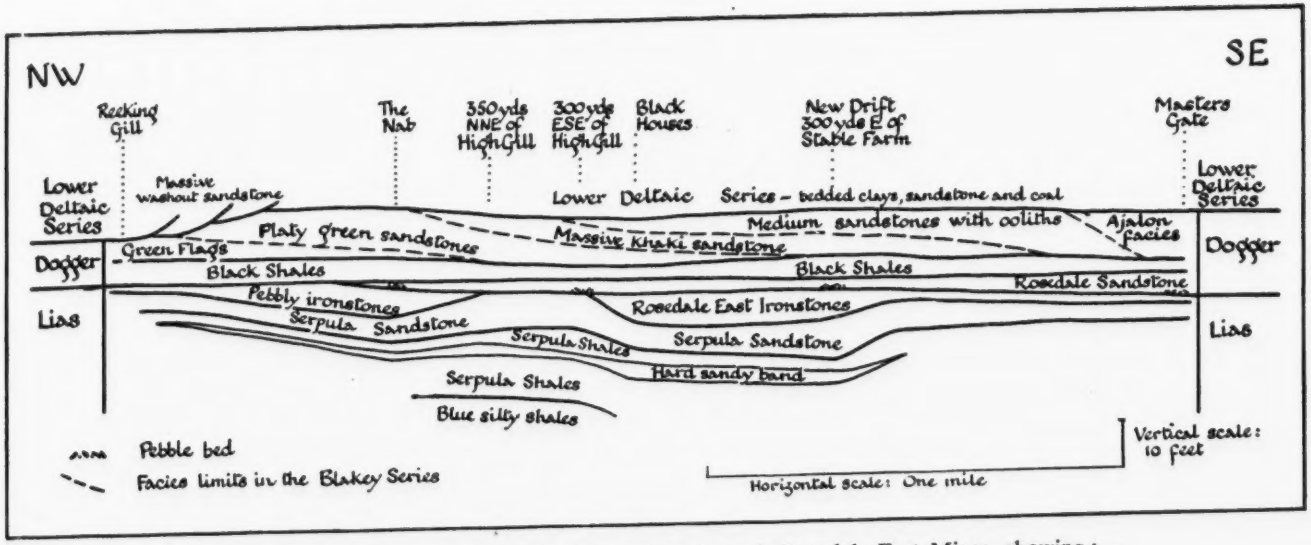
ordinary stone and showed a similar oolitic structure" (Fox-Strangways, etc., 1885). This rock is not exposed and no specimens are known.

Our measured section agrees closely with the oft-quoted "quarried face at Moor Hill, Rosedale East Mines" (Fox-Strangways, etc., 1885; Fox-Strangways, 1892, p. 170; Lamplugh, 1920, p. 30; Anderson, 1942, p. 30), a locality which has not been identified but which must be near here. In these published sections reference is made to the "Belemnite" of the ironstone miners, described as "a very poor and soft ironstone, full of casts of belemnites" (Fox-Strangways, etc., 1885). This bed apparently led to some confusion, for it was elsewhere analysed for iron (Lamplugh, 1920, p. 42), but it is clearly the Serpula Sandstone underlying the ironstone, a fine-grained sandstone feebly stained with limonite at outcrop and of no economic significance.

From the foregoing evidence it is claimed that the Rosedale East ironstone is not of Dogger (Inferior Oolite) age, as hitherto has been maintained (Fox-Strangways, etc., 1885; Lamplugh, 1920; Hallimond, 1925; Anderson, 1942), but is late Yeovilian. No direct faunal evidence for this is at present available. Field evidence shows, however, that this ironstone is a thicker and more oolitic representative of a widespread ironstone which in Danbydale to the north is of proved *dispansum* age (Rastall and Hemingway, 1943, p. 211). From the head of Rosedale this bed may be traced in successive exposures until it reaches a maximum at the mines. It would appear that the ironstone thickens in part by the addition of higher beds not represented to the north, but this cannot be proved. At the mines the ironstone is overlaid by a pebble bed or the pebbly base of the Dogger, which here as elsewhere marks the Lias-Oolite junction.

To the south-east of the mines the ironstone is not exposed for nearly a mile, but it is evident that it thins and deteriorates in this direction (Lamplugh, 1920, p. 30). Only the upper beds of the Dogger are exposed, usually deeply weathered khaki or deep red, ill-graded, pebbly sandstones of Ajalon aspect. At Master's Gate, near Bell Top, a complete succession shows the full effect of the changes, as follows :—

	ft.	*in.*
Lower Deltaic Series—		
Dark shales		
Dogger—		
Blakey Series—		
Ajalon facies : grading from a ferruginous sandstone near base to a fine oolite at top	10	0
Black shales, sandy at top	3	0
Rosedale sandstone—		
Greenish sandstone with ooliths and pebbly base . . .	5	6



TEXT-FIG. 2.—Section along N.E. side of Rosedale through Rosedale East Mines, showing :—
(*a*) the Lias-Oolite unconformity, consequent upon pre-Dogger folding.
(*b*) the wedging Rosedale Sandstone.
(*c*) facies variation in the Blakey (Dogger) Series.

	ft.	*in.*
Yeovilian—		
Siderite-mudstone with chamosite ooliths, calcite chips, and worm tubes	1	6
Serpula Series—		
Massive serpula sandstone	3	6
Shaly sandstone with occasional siderite-mudstone nodules with chamosite-ooliths	6	0
Sandy shale *seen*	6	0

Here the Rosedale East ironstone is represented by the much thinner and very low-grade siderite-mudstone. The Rosedale sandstone attains its maximum development. The Ajalon Oolite was worked for ironstone round Bell Top and Master's Gate in small opencasts, but the tonnage won was quite trivial compared with the Rosedale East ironstone.

The Ajalon facies may be traced up Northdale where, at the head, it is well exposed in West Beck, as follows :—

	ft.	*in.*
Lower Deltaic Series—		
Sandstone, flaggy and slumped	3	0
Shale	3	0
Coaly shale		6
Grey shale	10	0
Dogger—		
Blakey Series—		
Ajalon facies : grey chamosite-oolite with fine gravel-bed 4 feet from top	15	0
Rosedale Sandstone ?—		
Yellow sandstone	4	0
Yeovilian—		
Serpula Series—		
Fine-grained sandstone with belemnite casts and fossils in nests : harder beds feebly oolitic	3	0
Harder course of typical Serpula-bored sandstone	1	6
Alternating beds of purplish sandstone and shaly beds also oolitic	10	0
Sandy shales *seen*	6	0

This section is similar to that at Yew Grain, Great Fryup, only 1½ miles to the north (Rastall and Hemingway, 1943, p. 219) except in the development of poor ironstones in the Yeovilian, which may be also seen in North Gill to the east, where they have yielded *Trigonia* sp.

On the east side of Rosedale exposures are few, because the southerly dip carries the Lias-Oolite junction below the level of cultivation. Yeovilian rocks cannot be traced south of Stone Bank Crag and in Heygate Bank at 750 feet O.D., only a greenish sandstone with ooliths, a variant of the Blakey Series, is exposed. The profound changes that must take place in the next 1½ miles are hidden, but their extent may be seen in a collapsed trial hole for ironstone 150 yards north of Craven's Farm, where the succession shows no resemblance to those already described. Only a few feet of deeply weathered and now limonitized ironstone, originally a sideritic mudstone with chamosite ooliths, may

be seen, with a basal pebble bed, resting on blue Whitbian shale. The ironstone yielded an abundance of long-range lamellibranchs, with occasional brachiopods and gastropods, as follows :—

Lamellibranchs :
? *Astarte elegans* J. Sow.
Camptonectes laminatus (J. Sow) (= *lens* auct.).
Ceratomya bajociana (d'Orb.).
Cucullea sp. indet.
Gervillia tortuosa (J. de C. Sow.).
Gresslya abducta (Phillips).
Lima (*Plagiostoma*) *castertonense* Cox.
Lopha sp.
Modiolus cuneatus J. Sow.
Modiolus plicatulus J. Sow.
Pinna sp.
Pleuromya sp.
Protocardia ferruginea Rollier (= *Cardium striatulum* Phil. *non* Sow.).
Trigonia spinulosa (Young and Bird).
Velata abjecta (Phillips).

Gastropod :
Procerithium muricatum (J. de C. Sow.).

Brachiopod :
"*Terebratula*" *trilineata* (Young and Bird).

No ammonites were found. The fauna resembles, but is not identical with, the more extensive assemblage from the Glaisdale Oolite (ironstone), 6 miles to the north (Macmillan, 1932, p. 127), where the relative abundance of the species is also different. At Glaisdale, "*Terebratula*" *trilineata* and *Homoeorhynchia cynocephala* are outstandingly abundant, whereas at the Craven's Farm tip the latter form is not found, and *Lima* (*Plagiostona*) *castertonense* and *Velata abjecta* are dominant. It may be noted that here the trial drift was cut in shales *below* the Dogger and was presumably made in the hope of finding a continuation of the magnetite-oolite, which occurs on the opposite side of the dale.

On the west side of Rosedale the character of the rocks of the Lias-Oolite junction usually bears so little relationship to those on the opposite side of the dale, less than a mile away, that they will again be described in some detail (Text-fig. 3). For two miles south of the dale head, landslips lie on the contact and only fragments of the Danby Series and the Serpula Beds may be found. A complete section is exposed by the waterfall 500 yards west of High House, as follows :—

Dogger—	*ft.*	*in.*	*ft.*	*in.*
Blakey Series—				
Greenish, platey sandstone in beds up to 12 inches thick			12	0
Green Flag facies passing down to			2	6
Black Shales			3	2
Rosedale Sandstone—				
Coarse greenish sandstone with oolith relics and casts of *Terebratula*			2	2
Pebble bed				

	ft.	in.	ft.	in.
Yeovilian—				
Serpula Series—				
Lilac-grey ironstone with vertical worm tubes and scattered ooliths. Casts of *Pecten* and belemnites	1	8		
Clay with chamosite ooliths	1	4		
Grey siderite mudstone		6	6	2
Greenish clay	1	2		
Green oolitic ironstone	1	6		
Typical Serpula Sandstone			1	10
Pale grey clay	*seen*		10	0

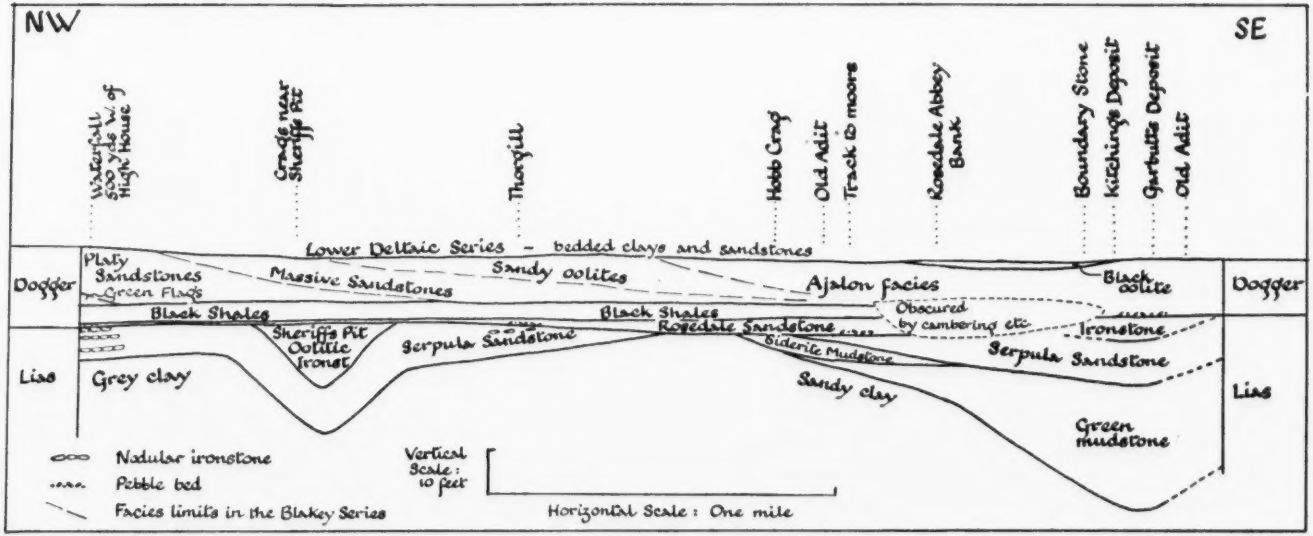
This exposure lies on the extrapolated south-east boundary of the exhausted area of the Rosedale East ironstone (Text-fig. 1). The poor ironstones and oolitic clays here present at the critical horizon represent, it is suggested, the feather edge of the original extent of the ironstone, which must have therefore extended about a mile south-west of its present outcrop. It may be said here that no trace of the Rosedale East ironstone has been found either on the west side of Rosedale, or in Farndale half a mile further south-west. Its form, after the pre-Dogger erosion, was most probably oval in plan, of which rather less than half was since eroded by the River Seven (Text-fig. 1).

Half a mile E.S.E. of the previous section the crags west of the old adits to Sheriff's Pit expose the following :—

	ft.	in.
Lower Deltaic Series—		
Massive feldspathic sandstone	20	0
Dogger—		
Blakey Series—		
Varying from a fine sandstone below to a greenish sandy oolite above	10	0
Black Shales	4	0
Yeovilian—		
Sheriff Pit Oolite—		
Green chamosite oolite, weathering brown	12	0
Serpula Series—		
Worm-bored sandstone	*seen*	2	0

From a locality near here, if not the same, Lamplugh recorded a similar section, but with double the thickness of shale (Lamplugh, 1920, p. 30). He also records that the ironstone, which he divided into four beds on a colour difference probably due only to weathering, rapidly thins out in all directions in the mine. He further states, rather remarkably, that the sandy upper bed of our Blakey Series, was worked for ironstone, though only at outcrop.

Again, there is no palaeontological evidence for the age of this ironstone. Its few fossils which occur crushed on occasional bedding planes are all of long range and therefore useless. Although the petrography is described later (p. 269) it may be said here that the Sheriff's Pit ironstone differs from that at Rosedale East in some of its lithological characters.



TEXT-FIG. 3.—Section through S.W. side of Rosedale showing :—

(*a*) two structural basins of pre-Dogger age, with Dogger resting unconformably across them.
(*b*) the lenticular Rosedale Sandstone.
(*c*) facies variation in the Blakey Series.

The magnetite oolite of Kitching's and Garbutt's Deposits is omitted from this section though the positions of their original outcrop are marked. On the exaggerated vertical scale of this diagram the magnetite-oolite deposits would extend as deep, narrow troughs from the base of the Dogger to a level below the base of the green mudstone.

In a steep moor-edge gully 400 yards south of Thorgill village and 1,000 yards south-east of Sheriff's Pit there is no ironstone. In view of its relative simplicity, in contrast to the succession both to the north-west and south-east, the section may be quoted.

	ft.	*in.*
Lower Deltaic Series—		
Massive sandstone	15	0
Dogger—		
Blakey Series—		
Fine sandstone near base passing up to coarser sandstone with ooliths	12	0
Black silty shales	3	6
Rosedale Sandstone—		
Greenish sandstone with ooliths	2	0
Pebble bed		
Yeovilian—		
Serpula Series—		
Soft, fine-grained, micaceous sandstone	3	0
Row of siderite-mudstone nodules		—
Soft greenish-yellow sandstone	2	0
Typical Serpula sandstone	4	0
Serpula Shales	10	0

The three Dogger members may be traced south-west below Hobb Crag with little change except that the Ajalon facies coarsens in grade and the Rosedale sandstone becomes more oolitic. The pebble bed develops into a prominent shaly layer with well-rounded pebbles up to 3 inches long. Near this point begins a series of changes in the Yeovilian succession which extend south-west beyond the magnetite mines. Three hundred yards south-west of Low House the Dogger, with its basal pebble bed, rests on a flinty siderite-mudstone with occasional ooliths, while in a gully 270 yards further east these beds are separated by 30 inches of typical Serpula Sandstone. Here again then is evidence of minor pre-Dogger folding within the main tectonic basin within which the Yeovilian is preserved (Rastall and Hemingway, 1943, p. 213). Additions to the Yeovilian succession are also initiated near here, for in the gully section 200 yards south of Low House, a greenish mudstone which assumes great importance in the magnetite mines 1,200 yards to the south-west, first appears beneath the siderite-mudstone. These beds may best be seen in a crag by the side of an old track to the moors, 200 yards S.S.E. of Low House, as follows :—

	ft.	*in.*
Lower Deltaic Series—		
Poor coal with seat-earth	1	6
Sandstone	2	0
Shaly sandstone	2	0
Carbonaceous shale	2	6

	ft.	in.
Dogger—		
Blakey Series—		
Variable sandy oolite, grey when fresh, slightly current bedded	10	0
Black Shales, silty at top	3	0
Rosedale Sandstone—		
Greenish massive sandstone with ooliths, wood fragments, shale flakes and layers of shell debris	5	0
Prominent pebble bed		3
Yeovilian—		
Serpula Series—		
Serpula-bored sandstone, greenish and micaceous, with belemnite and pentacrinus casts	3	8
Oolitic siderite-mudstone passing to	2	6
Ferruginous mudstone, greenish when fresh and shattered by irregular joints	2	0
Soft grey sandy shale with vertical *Gresslya donaciformis*	6	0
Blue shale	20	0

In Rosedale Abbey Bank (Rosedale Chimney), half a mile south of Rosedale Abbey village, the Yeovilian is not fundamentally altered, though severe cambering has hidden the lower beds of the Dogger. Ajalon oolite, with a capping of Black Oolite is typically developed and dips steeply valleywards.

South of the road the Ajalon Oolite was tried for ironstone and in the old tramway 270 yards south of Woodend Villa the Dogger is exposed. Here, the Black Oolite may be seen dying away to the south and below it is a variable oolite of the Ajalon facies.

The Yeovilian beds are exposed on the flanks of those parts of the two magnetite-oolite deposits which were worked by opencast methods, a mile S.S.E. of Rosedale Abbey village. On the north-west wall of Kitching's deposit is exposed :—

	ft.	in.
Dogger—		
Ajalon facies : yellow, brown, and soft oolite *seen*	2	0
Pebble bed in pasty mudstone matrix		2
Yeovilian—		
Serpula Series—		
Greenish micaceous chamosite-oolite	4	6
Green Serpula sandstone	10	0
Well-bedded shale *seen*	1	6
Mainly green mudstone, in part hidden	20	0
Green mudstone with scattered pebbles broken by irregular joints *seen*	8	6
Floor of old ironstone working		

Macmillan, who has recorded this section rather differently, has assigned the lowest bed to the *striatulum* zone and the remainder of the Yeovilian to the *dispansum* zone, though the upper 6 feet doubtfully so (Macmillan, 1932, pp. 129–130). The flanks of Garbutt's deposit immediately to the south show 12 feet of variable Ajalon facies and sandstone resting on 30 feet of Yeovilian beds, much of which is hidden.

This increase in thickness of that part of the Yeovilian from the greenish mudstone to the base of the Dogger from 8 feet in the gully 200 yards south of Low House, to at least 45 feet (Macmillan's estimate is 51 ft. 6 in.) on the flanks of the magnetite-oolite deposits is unique in north-east Yorkshire. It is brought about partly by synclinal folding before pre-Dogger peneplanation, but mainly by the development of beds not elsewhere represented, in particular the greenish mudstone. It is unfortunate that the Lias-Oolite junction is not exposed to the south-east until it reaches river-level 1½ miles away. Here, near Hartoft Bridge Farm, a sharply folded section shows about 20 feet of Dogger, grading up from a massive dark green oolitic ironstone to a grey sandstone with siderite lenses and resting upon blue-black Whitbian shales with *Meleagrinella sub-striata* (Munst). The Yeovilian is absent. In this distance there is hidden the entire south-east limb of this pre-Dogger syncline, which is also the south-east boundary of the Yeovilian rocks preserved in the main synclinorium (Text-fig. 4).

Farndale

Throughout Farndale the field relations of the Dogger-Lias junction are simple. Thus, in a small waterfall a quarter of a mile north of Blakey Mines is exposed the following :—

	ft.	*in.*
Lower Deltaic Series—		
Soft, well-bedded sandstone with soft jet	15	0
Dogger—		
Blakey Series—		
Massive greenish sandstone weathering spheroidally	6	0
Black silty shales	4	0
Yeovilian—		
Serpula Series—		
Siderite-mudstone		6
Blue argillaceous silt with worm tubes	12	0
Soft silty shales *seen*	6	0

The massive greenish sandstone is not always present, and usually the Dogger is represented in Farndale only by the Green Flags facies resting on a few feet of black shales. These two beds have been found throughout Farndale from an unnamed gill 700 yards north of Middle Heads, at the north-west corner of the dale to the Daleside Road at the south end. Frequently, as at Gill Wath, the base of a Lower Deltaic washout cuts irregularly into the Green Flags, and may even locally remove them, as on the hillside 250 yards south of Cross Farm. A minor variation in these usually constant flags is at Hollin Bank, where a 2 in. bed of limonitic ironstone crowded with plant debris suggests a bog iron ore formed during a minor elevation which carried the locality above the usual shallow-water marine environment.

Only at Blakey Mines is there any variation in the normal succession.

Here 10 feet of deeply boxed and very variable sandy oolite (Ajalon facies) has been worked on a small scale for ironstone. It passes up into Black Oolite, and its sandy base rests on a full development of the Danby Group.

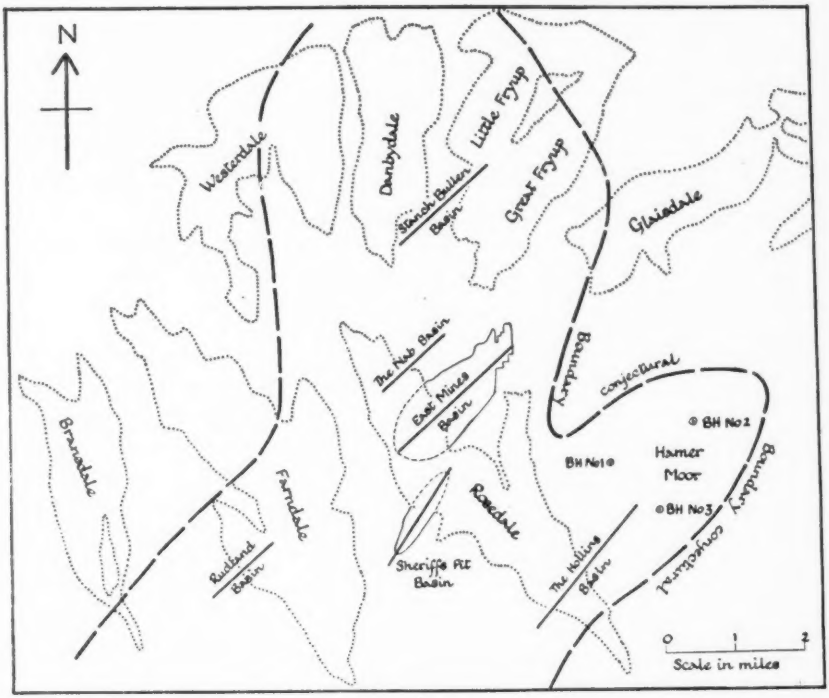
The massive Serpula Sandstone of *dispansum* age, so prominent near Rosedale East Mines, is not represented in Farndale except near Hollin Bank. Only silty clays, which elsewhere occur below the Serpula sandstone proper, are found, but they are confined to the east and south of the dale. Nor is the succession within these clays complete, since they frequently show one or more thin pebble beds, as in the gully 700 yards west of " Three Tuns " Inn and in the slip near Blakey Gill. When traced west, as at the head of Farndale, these grey and blue silty shales of *striatulum* age thin out, as at Potter's Nab. They are replaced, beneath the Black Shales of Inferior Oolite age, by blue-black shale of late Whitbian age, sometimes with a few inches of siderite mudstone at the junction, which has yielded *Nuculana*.

The Distribution of the Yeovilian

The belt of Yeovilian rocks, which in upper Eskdale and its tributaries is 4½ miles wide, continues south into Farndale, where its western limit, near Potter's Crag and Monket House Bank, can be traced with some accuracy, and into Rosedale, most of which lies within the belt. But below Stork House, at the south end of Bransdale, 18 inches of typical Serpula Clay below the Dogger indicates that here the edge of the belt swings further west (Text-fig. 4). Further, in each of the three Hamer Moor bore-holes sunk to the east of Rosedale to prove the Top Seam (i.e. the Dogger *s.l.*), several feet of " belemnite " or " belemnite ironstone " were recorded (Lamplugh, 1920, p. 43), proving a further extension of Yeovilian beds to the east. This Yeovilian outcrop pattern suggests folding of pre-Dogger age in a N.E.–S.W. direction, which is supported by the plan and orientation of the exhausted areas of the two ironstone mines of Rosedale East and Sheriff's Pit (Text-fig. 1). These are, from their ovate plan, neither ironstone-filled washouts nor, from the evidence at outcrop, belts of a ferruginous facies variation. All available evidence indicates that these ironstones are preserved in shallow basins of tectonic origin, elongated approximately N.E.–S.W.

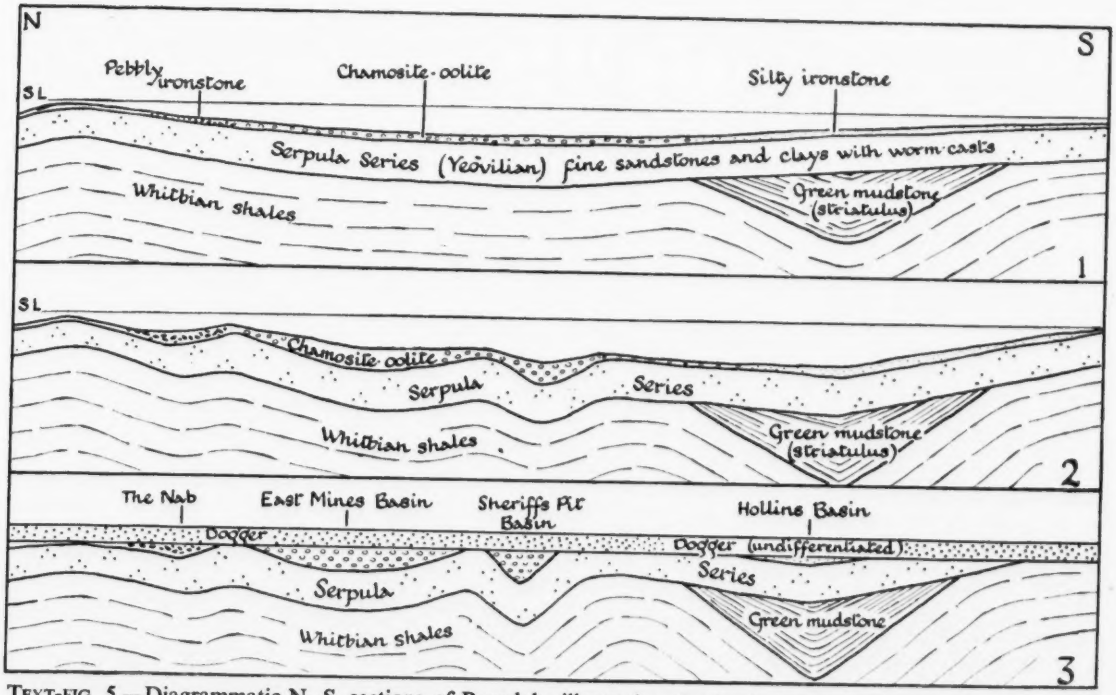
The age of the folding is undoubtedly pre-Dogger, as is shown by the unconformity at outcrop and the form of the worked areas. The several members of the Dogger sequence are unaffected by the folding, from which they are separated by a strong pebble-bed. Further, ironstone eroded from the crests of the elongated domes during the pre-Dogger planation contributed as pebbles, now part-phosphatized, to this bed both in the Rosedale area and also further afield (Rastall, 1905 ; Rastall and Hemingway, 1940, p. 272).

Several lines of evidence suggest that this folding may have been initiated during late Yeovilian times. Thus, the two ironstones at Rosedale East Mines and Sheriff's Pit, although similar in their essential constituents, differ in detail; for example, the relative proportions of siderite matrix and chamosite ooliths; the birefringence of



TEXT-FIG. 4.—Map showing the distribution of Yeovilian rocks (within the broken line) in the pre-Dogger structural basin. The black N.E.–S.W. lines indicate the major axes of smaller structural basins in the Yeovilian which together comprise the main basin. East Mines basin and Sheriff's Pit basin contained ironstones of past economic importance. The remaining basins hold impure low-grade ironstones of no value.

the chamosite; the distribution and abundance of the fossils. This suggests that the two ironstones were deposited in basins which, though not separate were developing individual characteristics. Further, in the Hollins Basin the development of 30 feet of silty chamosite mudstone *before* the Serpula sandstone of *dispansum* age, may indicate a long-continued downsinking of this area, with a consequent instability which gave rise to micro-slumping (p. 267).



TEXT-FIG. 5.—Diagrammatic N.–S. sections of Rosedale, illustrating the development of the Yeovilian ironstones and associated beds. Not to scale.

1. Deposition of Yeovilian ironstone with silty or pebbly margins within the Rosedale basin of sedimentation.
2. Development of late-Yeovilian folding dividing the main sedimentational basin into minor structural basins.
3. Dogger resting unconformably on Yeovilian and Whitbian.

Here also the oolitic ironstone at the top of the Yeovilian differs in detail from those at Rosedale East and Sheriff's Pit.

The Rosedale East basin is larger and shallower than that at Sheriff's Pit. The maximum thickness of ironstone at Rosedale East was claimed to be 14 feet (Fox-Strangways, etc., 1885, p. 26), though this is open to doubt. The maximum thickness of ironstone is, however, an indication of the amount of downfolding, and the boundaries of the worked area mark its thinning to 3 feet or slightly less. The Sheriff's Pit basin is more limited in area, with a maximum width of 600 yards of economically workable ironstone and a measured thickness at outcrop of 12 feet of ironstone (p. 212) which is probably not the maximum. Of the orientation of the Hollins Basin little can be said, since the ironstone here did not merit exploitation ; the occurrence of Yeovilian under Hamer Moor, however, supports an elongation to the north-east, roughly parallel to that of the other basins. A fourth basin, smaller than the others, lies north-west of that at Rosedale East. It preserves only the developing edge of the Yeovilian ironstone as seen at the Nab (p. 206), which is thinner, less ferruginous, and more phosphatic than in the Rosedale East basin.

Southern Farndale shows the effect of this folding in a less striking manner. The south-westerly extension of the Sheriff's Pit axis controls the distribution of the Serpula Sandstone near Hollins Bank. More significantly the south-west swing of the Yeovilian boundary in this dale is controlled by a shallow basin with its axis near Garnet's Crag, West Gill. This, however, preserves only siderite-mudstones in its ill-exposed trough.

The N.E.–S.W. alignment of the pre-Dogger basins in this area further suggests that the distribution of the Yeovilian in the Fryups and Danby is not controlled by a simple pre-Dogger tectonic basin elongated north–south, as was originally suggested (Rastall and Hemingway, 1943, p. 213), but by a series of smaller basins each elongated approximately N.E.–S.W. and arranged in echelon from north to south. In one of these the thin Stanch Bullen ironstone of Great Fryup (p. 222) is preserved.

Of the distribution of the Yeovilian beyond the geographical limits of this paper, with the possible location of further deposits of low-grade ironstone, a little may be said here. Considering only the ironstones from north-west to south-east across nearly all the folds detected, the pre-Dogger structure is that of a small synclinorium, with a maximum downfolding in the region of the two worked ironstones, and with decreasing intensities to the north and south. It will, therefore, be unlikely that further Yeovilian ironstones will be found in these directions unless fold-complexes at present unknown be located.

A second factor must also be taken into consideration, that is the

original extent of the low-grade ironstone. It is clear that at the Nab (p. 206) the pebbly and argillaceous succession is only that of a depositional margin to the main mass of ironstone. To the north the micaceous chamosite-oolite of Stanch Bullen, in Great Fryup (Rastall and Hemingway, 1943, p. 222), is of entirely different facies from that of Rosedale East, the two being separated by a ridge which supplies the pebbles found in the ironstone of the Nab. Further, the interfingering clays in the ironstone in the High House section and the quartz silt in the matrix of the chamosite-oolite of the Hollins Basin again suggests a marginal facies of the original ironstone " lagoon ". It may therefore be concluded that the Yeovilian ironstone did not originally extend far beyond the present limits of Rosedale.

No Yeovilian has yet been seen to the west in Bilsdale or on the western Cleveland escarpment. To the east, Yeovilian beds have long been recorded on the downthrow side of the Peak Fault [1] (Fox-Strangways and Barrow, 1915, p. 116, etc.) where they are thickening southwards into a pre-Dogger basin when they dip below sea-level (Rastall and Hemingway, 1939, p. 365). The Peak Fault is probably torn sinistrally and certainly Yeovilian deposits do exist between its southern extent and Rosedale. Lamplugh's unpublished notes on the Crosscliff bore (inset in Text-fig. 1) about 12 miles E.S.E. of Rosedale Abbey (Lamplugh, 1920, p. 44) which have recently been discovered, specifically deny the presence of " Blea Wyke Sands and Shales " (i.e. Yeovilian) in the bore-hole. Yet he records the following below the Dogger and above the Alum Shales :—

	ft.
" Micaceous and rather sandy shale : no fossils seen in the top 6 feet, but a few belemnites below : not many fossils in first 15 feet	15
Shales with many belemnites and shells of *Lima* type	20 "

From their lithology, belemnite content and stratigraphical position these beds may only be correlated with the Blea Wyke Beds of Yeovilian age. The overlying " Dogger " core had been removed at the time of Lamplugh's examination and its thickness and lithology were not recorded. It is therefore not possible to determine if a new fold-complex with ironstone is located near here, though certainly a single pre-Dogger basin is present. It may be compared, in its apparent isolation, to the localized patch of Yeovilian, also preserved in a pre-Dogger syncline and exposed in Roxby Beck, near Loftus (Rastall and Hemingway, 1943, Text-fig. 1).

The Distribution of the Rosedale Magnetite-Oolite

The field relationships of the two elongate masses of magnetite-oolite in south-west Rosedale are discussed here without prejudice to

[1] The detailed structure of the Peak Fault is under investigation by the junior author.

their age. They are Kitching's deposit to the north and Garbutt's deposit to the south, and each was from 5 to 6 acres in extent, with a maximum width of 150 yards and a maximum depth of about 32 yards (Marley, 1879–80). The sides of the " shale cheeks " on which the deposits rest were " irregular and shelvy " and on them occasional waterworn pebbles were found. These shale cheeks are still in part exposed in the opencast part of the workings (p. 215), where they show evidence of slickensides. Serial sections across the deposits show how they decreased in size to the west, until they terminated at about 440 yards and 600 yards respectively from their original outcrops, after some minor faulting. They also show that the floors of these trough-shaped deposits were irregularly inclined and that Garbutt's deposit almost thinned out 200 yards from its outcrop before swelling out again for a further 200 yards. The two deposits are never in contact and though sometimes spoken of as nearly parallel, would undoubtedly have met had they extended a hundred yards further west.

In his descriptions, upon which the above paragraph is based, Marley emphasizes that " the top seam actually overlies the magnetic stone at the quarry, forming the roof of the magnetic stone in drifting " (Marley, 1879–80, p. 194, etc.). The Top Seam is the term by which the Dogger (*s.l.*) was usually known by the ironstone miners, irrespective of its iron content, and in this case is the Ajalon facies, which is exposed on the flanks of the old workings. Its basal pebble bed is the same as that between the magnetite deposit and the Top Seam (Marley, 1879–80, p. 198). From this it is clear that the magnetite-oolite deposits are pre-Blakey Series in age. Further than this cannot be argued with certainty, though it is tempting to assume that they also predate the youngest Dogger of the district, but since these die out before reaching the magnetite mines this is unproven.

There is no evidence that the magnetite-oolite deposits are preserved in pre-Dogger tectonic basins, as are the low-grade ironstones further north. Although the original outcrop of the magnetite-oolite does coincide with the middle of the Hollins Basin, this is purely fortuitous, since the basin is elongated approximately north-east–south-west, whilst the magnetite deposits run almost east–west. Although evidence of pre-Dogger folding is not lacking, it was of insufficient intensity to preserve these two adjacent deposits in relatively deep tectonic basins. Indeed, the truncation of the several beds of the Yeovilian by the magnetite deposits is directly opposed to it. All evidence tends therefore to confirm the early view that the magnetite-oolite deposits lie in deep and narrow channels (Marley, 1879–80 ; Lamplugh, 1920, p. 28), cut in beds of *dispansum* and *striatulum* age. From the presence of waterworn pebbles on their shelving flanks, the channels are presumably stream-cut. They have been compared with the channels

filled with Dogger limestone and low-grade ironstone in Bilsdale, 10 miles to the north-west (Lamplugh, 1920), since proved to be of *murchisonae* and probably *scissum* age (Black, 1934), but the two groups differ profoundly in form. Although of the same maximum depth, those of Bilsdale are about ten times wider than the Rosedale troughs, while the Bilsdale group indicate a normal series of incised meanders, which are apparently continuous within the limits of outcrop, very different from the low-angle Rosedale pair. The Rosedale magnetite was characterized by " the entire absence of shells " (Wood, 1859), nor have any macroscopic or microscopic fossils been found in the few fragments which may now be collected. This is in contrast with the shell-bands and lamellibranch and echinoderm debris which make up much of the Bilsdale Dogger.

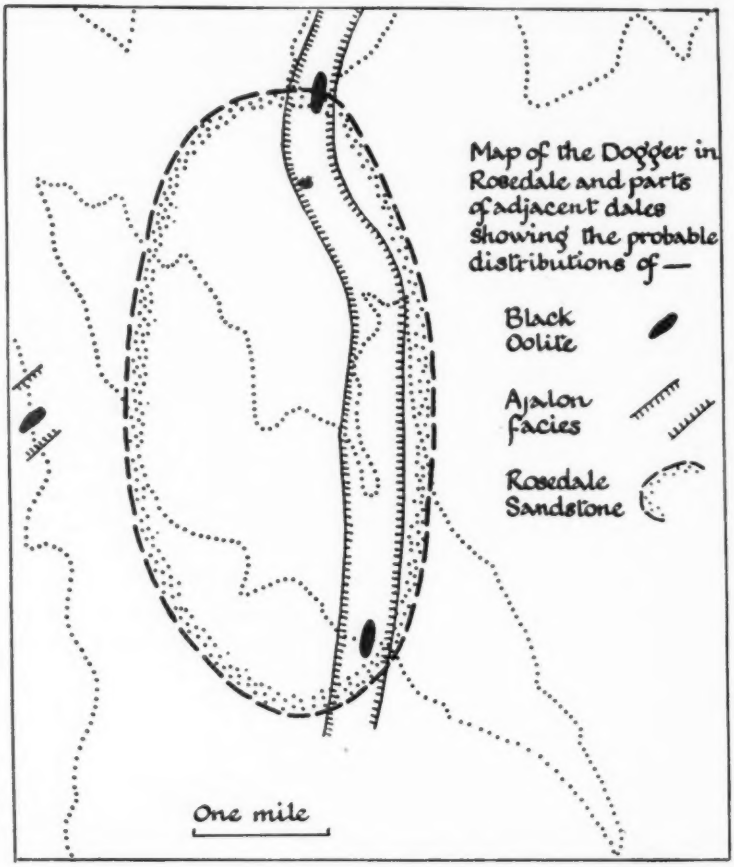
The Distribution of the Dogger

The distribution of the thin Rosedale Sandstone is shown in Text-fig. 6. Its relation to the main synclinorium is significant, in that it overlies the region of maximum pre-Dogger folding, near the old ironstone mines, and though its distribution was controlled by the down-warping which continued throughout Middle Jurassic times it was not influenced by Caledonoid folding.

The succeeding Black Shales and Green Flags facies are widespread and extend far to the west of Farndale. They, in turn, are followed by a platy green sandstone, which is succeeded by the Woodhead Scar sandstone, and finally by the various members of the Ajalon Series. In an earlier paper (Rastall and Hemingway, 1943, p. 213) we considered that these rocks were in chronological sequence, though each may have been partially or entirely removed by intra-formational erosion. However, the better exposed Rosedale sections and particularly those from Reeking Gill to Rosedale East Mines (pp. 204–10) admit the alternative interpretation of facies variation within this group of sandy rocks now referred to as the Blakey Series. This is supported by the absence of erosion surfaces between the several lithological types and by the gradual passage of one type to another in sections often continuous over many score of yards. Thus, from N.N.W. to S.S.E. the rocks above the Black Shales become progressively coarser in grain ; they pass from thin current-bedded flags to massive sandstones, etc. : and from non-oolitic to markedly oolitic and from chamositic to sideritic cements. Further, the thickness of these rocks is usually 10 feet to 12 feet ; in this they show a uniformity which would be unlikely if they had suffered successive episodes of erosion and deposition. Again, it would be most unlikely that intra-formational erosion would remove a sandstone, e.g. the Green Flags and fail to remove almost any part of the underlying Black Shales or leave evidence

of such erosion in the form of pebble beds. Gradual passage from the Black Shales to the overlying sandy beds is indeed common. The weight of evidence is therefore strongly in favour of facies variation.

It would appear reasonable to interpret this succession as indicating shallow inshore conditions in the Northdale region, where were laid


Map of the Dogger in Rosedale and parts of adjacent dales showing the probable distributions of —
Black Oolite
Ajalon facies
Rosedale Sandstone
One mile

TEXT-FIG. 6.—Sketch map of Rosedale and parts of adjacent dales showing the probable original distribution of the Rosedale Sandstone, the Ajalon facies, and the Black Oolite.

down massive, ill-graded, and pebbly Dogger sediments, mixed with ooliths derived from contemporary deposits. These were subsequently cemented with siderite. To the west lay deeper water and a less disturbed environment, where by contrast cementing chamosite was deposited interstitially among the well-bedded and finer detrital

sediment. It is noteworthy that in the Reeking Gill–Rosedale East sections the coarser or more massive or more oolitic beds always overlie the finer or more flaggy or less oolitic beds. The several facies belts thus moved progressively westwards or north-westwards, presumably under gradual emergence of the regions to the east. The Black Oolite of Ewe Grain and Rosedale Bank is probably therefore an inshore sand which acted as a stratigraphic oil trap under an impervious cover of clays of the Lower Deltaic Series, the oil being subsequently absorbed into the weathered ooliths and now existing in only a carbonized form.

(To be continued.)

New Lower Ordovician Brachiopods from the Llandeilo-Llangadock District

PART II

By Alwyn Williams

(PLATE XI)

(*Continued from p. 174*)

Orthacea Walcott and Schuchert 1908

Orthidae Woodward 1852- emend. Schuchert and Cooper 1932

Hesperorthinae Schuchert and Cooper 1931

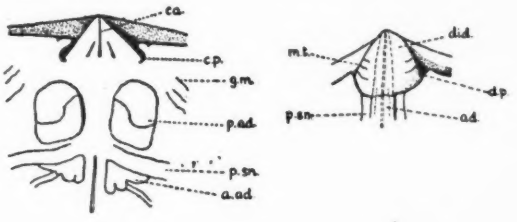
Hesperorthis Schuchert and Cooper 1931

Hesperorthis dynevorensis sp. nov.

Pl. XI, figs. 1 and 2, Text-fig. 1

Dimensions.—

			Length. cm.	*Breadth.* cm.
Syntypes.				
(1)	Internal mould of dorsal valve	G.S.M. 75,259	2·2	2·6
(2)	Internal mould of ventral valve	G.S.M. 75,260	2·3	2·5 (est.)
(3)	,, ,,	G.S.M. 75,261	—	—



a *b*

Text-fig. 1 (*a*).—Dorsal postero-lateral region of *Hesperorthis dynevorensis* sp. nov. (syntype 1). × 1½ approx. a.ad., anterior adductor; ca., cardinal process; c.p., crural process; g.m., genital markings; p.ad., posterior adductor; p.sn., pallial sinus.

(*b*).—Ventral umbonal region of *Hesperorthis dynevorensis* sp. nov. (syntype 2). × 1½ approx. ad., adductor scar; did. diductor scar; d.p., dental plate; m.t., muscle track; p.sn., pallial sinus.

External characters.—Plano-convex with a moderately deep ventral valve and a plane to slightly convex dorsal valve. Outline is semi-oval with the greatest width just anterior to the long straight hinge-line. Ventral interarea, wide, long, apsacline, dorsal interarea, anacline.

Ribbing.—Costate, 32 to 34 simple primary ribs, set rather apart, with the interspaces crenulated by lines of growth.

Internal characters.

Dorsal valve.—Hinge-line forming a thick " bar " supporting the notothyrial cavity, which extends postero-dorsally and is bounded laterally by two lamellar rudimentary crura projecting anteriorly.

The notothyrial cavity contains medianly a thin rod-like cardinal process which narrows to a point posteriorly. A pair of deep sockets lie lateral to the crura.

The " bar " effect of the hinge-line is such that the posterior adductors, an oval pair of scars notched on the inside, are indented somewhat into the " bar ". A median ridge extends anteriorly from the " bar " and bears on its surface a faint, thin, longitudinal impression. The posterior adductors are separated from the smaller anterior, somewhat flabellate, adductors by a pair of prominent vascular trunks which bifurcate laterally. A smaller pair of branches arise from the anterior adductor and divide into two peripherally. Genital markings are visible postero-laterally. Periphery bears impressions of costae split medianly.

Ventral interior.—Delthyrial cavity, deep, open. Crural fossettes small. Teeth small, supported by a pair of strong dental lamellae. A bounding ridge of adventitious matter encloses the muscular area almost completely, but medianly it is subordinate to the impression of the adductor scar. Two adductor scars, thin and long, separated by a fine ridge, project considerably beyond the diductors. Diductor scars, broad, triangular, contained within the delthyrium, and bearing oblique muscle tracks. Pallial markings obscure, a pair of primaries arising from the anterior limits of the diductors. Periphery ribbed, with split costae.

Type horizon.—Lower Pebble Bed of Upper Llanvirn.

Type locality.—Outcrop, 100 yards S. of the Old Castle, Dynevor, Llandeilo.

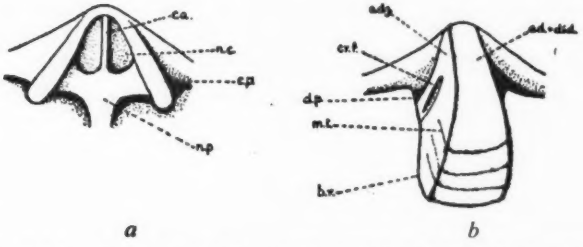
Discussion.—The new species may eventually prove to be quite distinct from *Hesperorthis*, for it is unique in the absence of ventral ovarian impressions, rudimentary deltidium and chilidium, and in having the anterior adductor smaller than the posterior in the dorsal valve. The former structures, however, seem to be somewhat variably developed and the dorsal valve of *Hesperorthis tricenaria* (Conrad) figured by Schuchert and Cooper (1932, pl. 4, fig. 21) also shows the anterior adductor scars smaller than the posterior ones.

It is interesting to note that *H. dynevorensis* bears a close internal resemblance to *Dolerorthis psygma* and *D. reedi* (Lamont and Gilbert 1945, pp. 645–651), and the dorsal valve is very much like that figured by them as the dorsal interior of *Dolerorthis rustica* (fig 2, p. 650). Indeed, the only fundamental diagnostic character which immediately distinguishes this new species from the Dolerorthids is the reversed convexity of the valves, and it is this characteristic that the author has used for the generic distinction between *Hesperorthis* and *Dolerorthis* (see Lamont and Gilbert, p. 649).

Paurorthis Schuchert and Cooper 1931

Paurorthis turgida (McCoy) emended

Pl. XI, figs. 9, 10, and 11, Text-fig. 2



a *b*

TEXT-FIG. 2 (*a*).—Cardinalia of *Paurorthis turgida* (McCoy) (new material 3). × 3. ca., cardinal process; c.p., crural process embedded in adventitious matter; n.c., notothyrial cavity; n.p., notothyrial platform.

(*b*).—Ventral umbonal region of *Paurorthis turgida* (McCoy) (new material 1). × 3. ad. & did., fused adductor and diductor scars; adj., ? adjustors, scar; b.r., bounding ridge to muscle scar; cr.f., crural fossette; d.p., dental plate; m.t., muscle track.

Orthis turgida McCoy 1851, 399–400 *pars*.

Orthis turgida McCoy 1852, 299 *pars*, pl. 1H, fig. 21, *non* figs. 20, 22, 23, 24.

Orthis turgida Davidson 1871, 258, pl. xxxii, fig. 13, *non* figs. 10–12, 14–20.

Orthis turgida Davidson 1883, 187, pl. xiv, fig. 20, *non* figs. 17–19.

Linoporella ? *turgida* Schuchert and Cooper 1932, 150–2.

Orthis turgida was first described by McCoy in 1851, and again in 1852, the later description being accompanied by illustrations of specimens which formed the basis of his diagnosis. The figured types were collected from a variety of places: pl. 1H, figs. 20 and 20*a*, represents an external cast of a dorsal valve from the Llandeilo Limestone (A16,679); fig. 21 an internal mould of a ventral valve from Golden Grove, Llandeilo (A11,100); figs. 22 (A16,680) and 23 (A11,101), internal moulds of dorsal valves from Craig-y-beri, and the Hills north of Conway respectively; fig. 24 represents a reconstructed anterior view of conjoined valves, but is a composite representation and need not be considered further. It now appears that all the figured dorsal valves are generically distinct from the figured ventral valve. The former are described below as Corineorthis spp. and the latter is here chosen as the lectotype for *P. turgida* emended.

This ventral valve is preserved in a rather coarse ashy sandstone, which could only have come from the quarry of Ffairfach Grit, at Golden Grove. No specimens comparable with it have been collected

from this locality, but at Ffairfach numerous ventral valves conspecific with that from Golden Grove and associated with dorsal valves described below have been obtained from strata some 50 feet above the horizon of the Golden Grove locality.[1] Accordingly new material has been chosen from among the Ffairfach specimens to provide a complete description of *P. turgida* emended.

Dimensions.—		*Length.* cm.	*Breadth.* cm.
Lectotype.			
Internal mould of ventral valve	S.M.A. 11,100	1·0	—
New material.			
1. Internal mould of ventral valve	G.S.M. 75,255	1·8	1·7
2. ,, ,,	G.S.M. 75,256	1·3	1·1
3. Internal mould of dorsal valve	G.S.M. 75,257a	1·5	1·6
4. ,, ,,	G.S.M. 75,257b	1·2	1·3
5. External impression of interareas and portions of both valves	G.S.M. 75,258	—	—

External characters.—Sub-circular in outline with a wide hinge-line (not the greatest width of the shell, which is anterior to the hinge-line). Strongly bi-convex, the ventral valve sometimes slightly more so than the dorsal. Ventral interarea curved, apsacline; dorsal interarea anacline, notothyrium, and delthyrium open. Ornamentation poorly preserved, multicostellate, with strong concentric lines of growth.

Internal characters.

Ventral valve.—Delthyrial cavity moderately deep, teeth conspicuous, with accessory sockets. Crural fossettes distinctive, oblique, and substantiated by a thick fossette ridge. Dental plates short, continued anteriorly by ridges of adventitious matter to form a lateral boundary to the musculature. Muscle scar sub-rectangular; in mature shells up to half the length of the shell and almost three times as long as wide. In young and mature shells the adductor and diductor scars occupying two slight, parallel tumescences are seen to extend anteriorly beyond the adjustors (?) which occupied the dental plates and part of the delthyrial cavity. In gerontic individuals the muscle scar is rather obscured by the presence of muscle tracks and the thickened boundary only breaks down anteriorly.

Dorsal valve.—Notothyrial cavity shallow, bounded by two divergent blunt brachiophores supported by adventitious material which also builds up a bulbous notothyrial platform. Sockets lateral to the brachiophores are not deeply impressed. Cardinal process forms a simple rod. The notothyrial platform is continued anteriorly as a

[1] The matrices for the lectotype and the new material seem to be identical and the fact that *P. turgida* has only been collected from this one locality in the Llandeilo area where, however, numerous casts can be obtained, suggests that the Ffairfach cutting was the actual locality for the lectotype as well.

broad high septum which divides the brachial valve into two and tends to splay out at the anterior margin. Muscle scars are not distinguishable.

Type horizon.—Upper Llanvirn.

Lectotype locality.—Quarry, 1 mile W. of Golden Grove mansion, Llandeilo.

New material.—Ffairfach railway cutting, 60 yards S. of the level-crossing.

Discussion.—Schuchert and Cooper (1932, p. 151) provisionally placed *P. turgida* in the Dalmanellid genus *Linoporella* on the characters exhibited by the dorsal valve, which, as seen above, does not belong to *P. turgida* emended. *P. turgida* can be relegated to the genus *Paurorthis* Schuchert and Cooper on its external and internal characters, but differs from typical species in its much larger size, in the absence of the median septum of the ventral valve, and the absence of ovarian impressions. None of these, however, would seem to warrant generic recognition. The ventral septum is " not constant in all specimens [of *Paurorthis*], some having a rather wide median undulation " (Schuchert and Cooper, 1932, p. 80), and the absence of ovarian markings may even be due to the coarseness of the matrix in which the specimens are preserved.

PLECTORTHIDAE Schuchert and Cooper 1930

Corineorthis Stubblefield 1939

Corineorthis pustula sp. nov.

Pl. XI, figs. 3–6, Text-fig. 3

Orthis turgida McCoy 1851, 399–400 *pars.*

Orthis turgida McCoy 1852, 299 *pars*, pl. 1H, figs. 20, 22, 24, *non* figs. 21, 23.

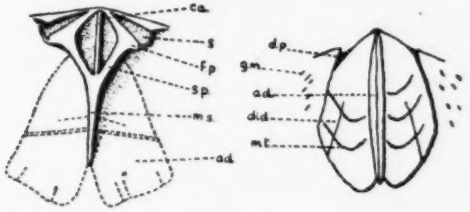
Orthis turgida Davidson 1871, 258 *pars*, pl. xxxii, figs. 12, 14, 16; ? figs. 17, 18, 19, 20; *non* figs. 13, 15.

Orthis turgida Davidson 1883, 187 *pars*, pl. xiv, fig. 17, ? fig. 18, *non* figs. 19, 20.

Linoporella ? *turgida* Schuchert and Cooper 1932, 150–152

Dimensions.—		*Length.* cm.	*Breadth.* cm.
Syntype 1.			
External cast of dorsal valve	A16,679	—	—
New material.			
1*a*. Internal mould of dorsal valve	G.S.M. 75,262	1·8	2·2
1*b*. External cast of dorsal valve	G.S.M. 75,263a	1·7	1·9
1*c*. Internal mould of ventral valve	G.S.M. 75,264	1·7	2·2
1*d*. External cast of ventral valve	G.S.M. 75,265	1·5	—

Dimensions.—		*Length. cm.*	*Breadth. cm.*	
1*e*. Cardinalia of dorsal valve	G.S.M. 75,263b	—	—	
1*f*. Internal mould of dorsal valve showing muscle scars	G.S.M. 75,266	—	—	
Syntype 2. Internal mould of dorsal valve	A16,680	—	—	
New material.				
2*a*. External casts of dorsal valve	A25,313, A25,315	1·6	1·7	(others fragmentary)
2*b*. Internal mould of ventral valve	A25,323	fragmentary		
2*c*. Internal mould of dorsal valve (young)	A25,321	1·0	1·1	
2*d*. Internal mould of dorsal valve	A25,322	fragmentary		



a *b*

TEXT-FIG. 3 (*a*).—Cardinalia of *Corineorthis pustula* sp. nov. (new material 1*a*). × 3. ad., adductor scar ; ca., cardinal process ; f.p., fulcral plate ; m.s., median septum ; s., socket ; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Corineorthis pustula* sp. nov. (new material, 1*c*). × 3. ad., adductor scar; did., diductor scar ; d.p., mould of dental plate ; g.m., genital markings ; m.t., muscle tracks.

External characters.—Typical Orthoid outline to dorsal and ventral valves with the greatest width anterior to the hinge-line. Dorsal valve strongly convex, with a well-marked median sinus, widening very gradually anteriorly, umbo incurved. Ventral valve convex posteriorly, with a small umbo, but peripherally flat to concave.

Ribbing system.—Multicostellate on the primitive plan (with up to 12 primaries), viz. 1 primary, secondary (*a*), secondary (*b*), tertiary, but with a marked change from external to internal development (and vice versa) with the changing shape of the shell. Finely developed concentric ridges between ribs, coarsely exopunctate.

Dorsal valve.—

1$\bar{a}$, 1$\bar{b}$, 1.
2$\bar{a}$1, 2$\bar{a}$, 2$\bar{a}$1, 2$\bar{b}$, 2.
3$\bar{a}$1, 3$\bar{a}$, 3, 3a° (strong).
4$\bar{a}$, 4$\bar{a}$1°, 4b, 4, 4b°, 4a°, 4a1°.
5$\bar{a}$, 5$\bar{a}$1°, 5, 5b°, 5a°, 5a1°
6, 6b°, 6a°, 6a1°.
7, 7b°, 7a°, 7a1°.
etc.

Ventral valve.—

1a°, 1b°, 1, 1b°, 1a°, 1a1°.

Right.	*Left.*
2$\bar{a}$, 2, 2b°, 2a°, 2a1°.	2$\bar{a}$, 2, 2b°, 2a°, 2a1°.
3, 3c°, 3b°, 3a°, 3a1°.	3$\bar{a}$, 3, 3c°, 3b°, 3a°, 3a1°.
4$\bar{a}$, 4, 4a°$\bar{1}$, 4a°, 4a1°.	4a$\bar{1}$, 4$\bar{a}$, 4$\bar{b}$, 4, 4a°$\bar{1}$a°, 4a°$\bar{1}$, 4a°.
5$\bar{a}$, 5, 5a°$\bar{1}$, 5a°, 5a1°.	5a$\bar{1}$, 5$\bar{a}$, 5$\bar{b}$, 5, 5a°$\bar{1}$, 5a°.
6a$\bar{1}$, 6$\bar{a}$, 6$\bar{b}$, 6, 6a°$\bar{1}$, 6a°.	6a$\bar{1}$, 6$\bar{a}$, 6$\bar{b}$, 6, 6a°$\bar{1}$, 6a°, 6a1°.
etc.	etc.

Internal characters.

Dorsal valve.—Cardinalia delicate, consisting of a pair of divergent crural processes and a slender, simple cardinal process contained within the notothyrial cavity. The crural processes are made up of a pair of supporting plates bounding the notothyrial cavity, and converging anteriorly to unite with the median septa, and a pair of fulcral plates which lie anterior to the deeply impressed dental sockets. Muscle scars faint, sub-triangular in outline, with the larger posterior adductors separated from the quadrangular anterior adductors by a ridge. Ribbing is impressed on the internal moulds of both valves.

Ventral valve.—Umbonal region rather deep with a pair of subparallel dental lamellae running anteriorly, and bounding laterally the pronounced muscular impression. The latter consists of a pair of diductor impressions, rounded anteriorly, separated by an elongated pair of adductors. Occasionally a pair of short divergent pallial sinuses are preserved, lying immediately anterior to the muscle scar. The areas lateral to the muscle scars are coarsely pustuled, with genital markings.

Type horizon.—Lower Llandeilo.

Type localities.—Syntype 1, Llandeilo, exact locality unknown. New material (1*a*–1*f*), outcrop 75 yards S.W. of St. Tyfei's Church, Llandeilo. Syntype 2 and new material (2*a*–2*d*), Craig-y-beri, Llanarmon.

Discussion.—The new species is a Corineorthid, but differs from the type species *Corineorthis decipiens* Stubblefield in the following characters.

(1) The greater convexity of the dorsal valve, with corresponding emphasis of the sinus.

(2) The greater emphasis of the muscle scars.

(3) The ventral valve of *Corineorthis pustula* is always coarsely pustulated postero-laterally.

Corineorthis globosa sp. nov.

Pl. XI, figs. 7 and 8, Text-fig. 4

Orthis turgida McCoy 1851, 399–400 *pars.*

Orthis turgida McCoy 1852, 299 *pars*, pl. 1H, fig. 23, *non* figs. 20–22, 24.

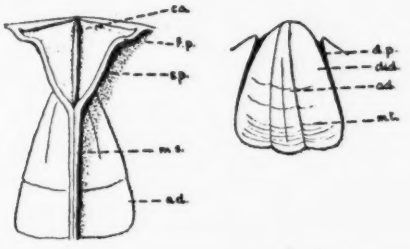
Orthis turgida Davidson 1871, 258 *pars*, fig. 15, ? figs. 17, 18, 19, 20, *non* figs. 12, 13, 14, 16.

Orthis turgida Davidson 1883, 187 *pars*, fig. 19, *non* figs. 17, 18, 20.

Linoporella ? *turgida* Schuchert and Cooper 1932, 150–152.

Dimensions.—

		Length. cm.	*Breadth. cm.*
Holotype.			
Internal mould of dorsal valve	A11,101	1·3	1·3
New material.			
Internal mould of dorsal valve	A25,304	1·3 (est.)	1·5
Internal mould of ventral valve	A25,305	Posterior portion	
Fragment of external cast of ? dorsal valve	A25,306		



a *b*

TEXT-FIG. 4 (*a*).—Cardinalia of *Corineorthis globosa* sp. nov. (A11,101). × 3, ad., adductor scar ; ca. cardinal process ; f.p., fulcral plate ; m.s., median septum ; s.p., supporting plate.

(*b*).—Ventral umbonal region of *Corineorthis globosa* sp. nov. (A25,305). × 3. ad., adductor scar ; did., diductor scar ; d.p., mould of dental plate ; m.t., muscle tracks.

External characters.—Subcircular in outline, with the greatest width anterior to the hinge-line. Subequally bi-convex, the dorsal valve globose, the ventral valve gently convex posteriorly. Valves ornamented by multicostellate ribbing and by occasional coarse, concentric lines of growth. Ventral interarea apsacline, dorsal interarea anacline-hypercline.

Internal characters.

Dorsal valve.—Cardinalia rather delicate, with a pair of widely divergent crural processes on either side of the notothyrial cavity, which contains a simple linear cardinal process. The crural processes consist of a pair of supporting plates, which converge with the median septum anteriorly, and a pair of splayed fulcral plates, forming anterior boundaries to the dental sockets. Median septum narrow, high, extending to half the length of the valve. Adductor scars deeply impressed, lateral boundaries well defined. Postero-lateral areas striated by genital markings. Ribbing very faintly impressed.

Ventral valve.—Delthyrium triangular, open; teeth supported by a pair of strong dental plates which extend anteriorly to form lateral boundaries to the strongly impressed muscle scar. Adductor scar moderately wide, median, and bounded by a pair of diductors traversed by muscle track impressions.

Type horizon.—Lower Bala.

Type locality.—" Hills N. of Conway Falls."

Discussion.—The new species is distinct from *Corineorthis decipiens* Stubblefield and *C. pustula* sp. nov. in its extremely globose dorsal value, the widely splayed fulcral plates, the strong muscle dorsal impressions, the presence of genital striae postero-laterally in dorsal moulds, and the wider adductor scar in the ventral valve. Except for the marked convexity of the dorsal valve, *Corineorthis globosa* is very like *C. salteri* (Davidson), and this group of shells may eventually prove distinct from *Corineorthis* (s.s.).

Strophomenacea Schuchert 1896

PLECTAMBONITIDAE Kozlowski 1929

Sowerbyella Jones 1928

Sowerbyella antiqua Jones var. *llandeiloensis* var. nov.

Pl. XI, fig. 12–14

Dimensions.—

		Length. cm.	*Breadth.* cm.
Syntypes.			
(1) External cast of ventral valve	G.S.M. 75,267	0·8	1·55
(2) Internal mould of ventral valve	G.S.M. 75,268	0·8	1·7 (est.)
(3) Internal mould of dorsal valve	G.S.M. 75,269	0·7	1·4
(4) External cast of dorsal valve	G.S.M. 75,270	0·7 (est.)	1·4 (est.)

External characters.—Semi-oval in outline, widest at the hinge-line, which is mucronate. Ventral valve is strongly convex, carinate, dorsal valve concave. Ornamentation fine, radial, consisting of a series of thread-like ribs averaging 7 to 8 per mm., with every fourth or fifth strongly accentuated and extending to the umbo.

Internal characters.

Ventral valve.—Comparable with *S. antiqua*, except that the umbonal region is deeper, and the septal groove dividing the adductors impressions more definite. In gerontic individuals a pair of vascular trunks are seen to arise from the muscular impressions, and reach almost to the anterior border, where they bifurcate. The muscle scars are bounded by a pair of thin, slightly divergent dental lamellae.

Dorsal valve.—Like *S. antiqua*, but the muscle scar is very markedly raised anteriorly and is distinctly divided by a median septum, and by four lateral septa, and the periphery is coarsely pustuled.

Type horizon.—Upper Llanvirn and Lower Llandeilo.

Type localities.—Syntypes (1) and (3) from outcrops 5 yards N. of Old Dynevor Castle, Llandeilo. Syntypes (2) and (4) from Quarry, 75 yards W. of Boathouse, Dynevor, Llandeilo.

Discussion.—The new variety is comparable with and penecontemporary to *S. antiqua*, but externally it differs in the finer ribbing, the differentiation into primaries, the semi-oval outline, with the "winged" hinge-line and the larger size. Internally, all characters, when compared with *S. antiqua*, are emphasized: e.g. the deeper umbonal region of the ventral valve; the elevation of the muscular area, and the pustules of the dorsal valve.

Rhynchonellacea Schuchert 1896

CAMAROTOECHIIDAE Schuchert and Le Vene 1929

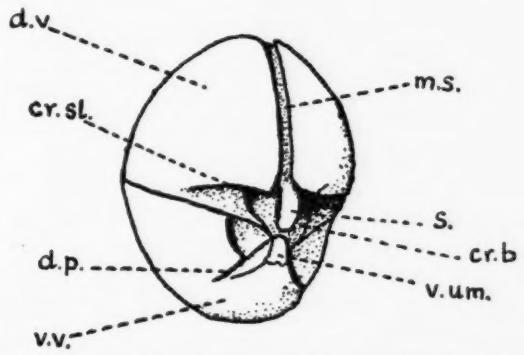
Rostricellula Ulrich and Cooper 1942

Rostricellula triangularis sp. nov.

Pl. XI, figs. 15–18, Text-fig. 5

Dimensions.—

Syntypes.		*Length. cm.*	*Breadth. cm.*
(1) Internal mould of dorsal and ventral valves interlocked	G.S.M. 75,229	—	—
(2) Internal mould of ventral valve	G.S.M. 75,230	0·85	1·0
(3) External cast of Syntype (2)	G.S.M. 75,232a	0·85	1·0
(4) Internal mould of dorsal valve	G.S.M. 75,231	0·85	1·0
(5) External cast of Syntype (4)	G.S.M. 75,232b	0·85	1·0



TEXT-FIG. 5.—Posterior view of *Rostricellula triangularis* sp. nov. (syntype 1). × 10 approx. d.v., dorsal valve; v.v., ventral valve; cr.b., crural base; cr.s., crural slot; d.p., dental plate; m.s., median septum; s., mould of septalium; v.um., ventral umbo (broken).

External characters.—Both valves about as wide as long, triangular in outline, with the greatest width at two-thirds the length. Moderately and subequally bi-convex, the dorsal valve having a broad, well defined fold, the ventral valve a complementary sulcus. The surface is ornamented with large radiating primary plications, three in the sulcus of the ventral valve, five on the fold of the dorsal valve, with five to six on either side.

Internal characters.—Best studied in the interlocked internal moulds of the dorsal and ventral valves of the holotype.

In the dorsal valve the hinge-line is short and somewhat curved, the median septum is well defined, reaching half the length of the valve, and posteriorly bifurcating to form a minute spindle-shaped septalium which does not contain a cardinal process. The sides of the septalium are fused to the hinge-line by a pair of acutely triangular, slightly concave plates (termed the "crural bases" by St. Joseph, 1937). It is undecided whether these are discrete or whether they are an extension of the hinge-line, but together with the split septum they simulate the socket and supporting plates of the Dalmanellids, and indeed have the same function, for the bases of the triangular plates support a pair of short simple crura diverging slightly anteriorly.

In the ventral valve the umbo is moderately high and bent over. From the disposition of the component parts it is deduced that the foramen is sub-apical (nothing is known of the deltidium). The teeth are strong, closely set, triangular in shape, resting upon the concave areas of the crural bases, and are supported by a pair of dental lamellae, bent sharply anteriorly, which appear as slots in moulds. No muscle scars have been observed. Ribbing is impressed in internal moulds of both valves.

Type horizons.—Upper Llanvirn and Lower Llandeilo.

Type localities.—Syntype (1): Upper Llanvirn outcrops in stream 200 yards N.W. of Bryntowy Farm, $1\frac{3}{4}$ miles S.S.W. of Llangadock. Other Syntypes: old quarry of Lower Llandeilo flags, 300 yards W. of Ysgubor-wen Farm, $1\frac{1}{4}$ miles E. of Llandeilo.

The new species is rather like *Rostricellula rostrata* Ulrich and Cooper, genotype of the genus, but differs in having a more triangular outline and a less globose contour than the latter.

The genus is interesting in that it probably includes species which were ancestral to the Silurian Rhynchonellids, viz. *Rhynchotreta* and *Camarotoechia*. Hall (1894) in his revision of the Rhynchonellids gave, as the prime distinction between *Rhynchotreta* and *Camaroteochia*, the presence of a cardinal process in the former and its absence in the latter. In 1937 St. Joseph, in two illuminating papers respectively dealing with the genoholotypes of *Rhynchotreta* and *Camarotoechia*,

pointed out that in fact a cardinal process was absent in *Rhynchotreta* as well as *Camarotoechia*, and presented a valid case for using such characters as dentition, and the presence of a septalium as the chief diagnostic characters of the respective genera. Following upon this, the specimens described above bear a strong resemblance to *Camarotoechia* in the possession of a true medium septum and a septalium. The crura, however, with their narrow crural bases, the strong triangular teeth of the ventral valve, together with the distinct dental lamellae supporting them are all characteristic of *Rhynchotreta*.

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PLATE

All figures 1½ times natural size except where indicated.

Hesperorthis dynevorensis sp. nov.

FIG. 1.—Internal mould of dorsal valve (G.S.M. 75,259).
FIG. 2.—Internal mould of ventral valve (G.S.M. 75,260).

Corineorthis pustula sp. nov.

FIG. 3.—Internal mould of dorsal valve (G.S.M. 75,262).
FIG. 4.—Internal mould of ventral valve (G.S.M. 75,264).
FIG. 5.—External cast of dorsal valve (A16,679).
FIG. 6.—Internal mould of dorsal valve (A16,680).

Corineorthis globosa sp. nov.

FIG. 7.—Internal mould of ventral valve, posterior aspect (A25,305).
FIG. 8.—Internal mould of dorsal valve (A11,101).

Paurorthis turgida (McCoy) emended.

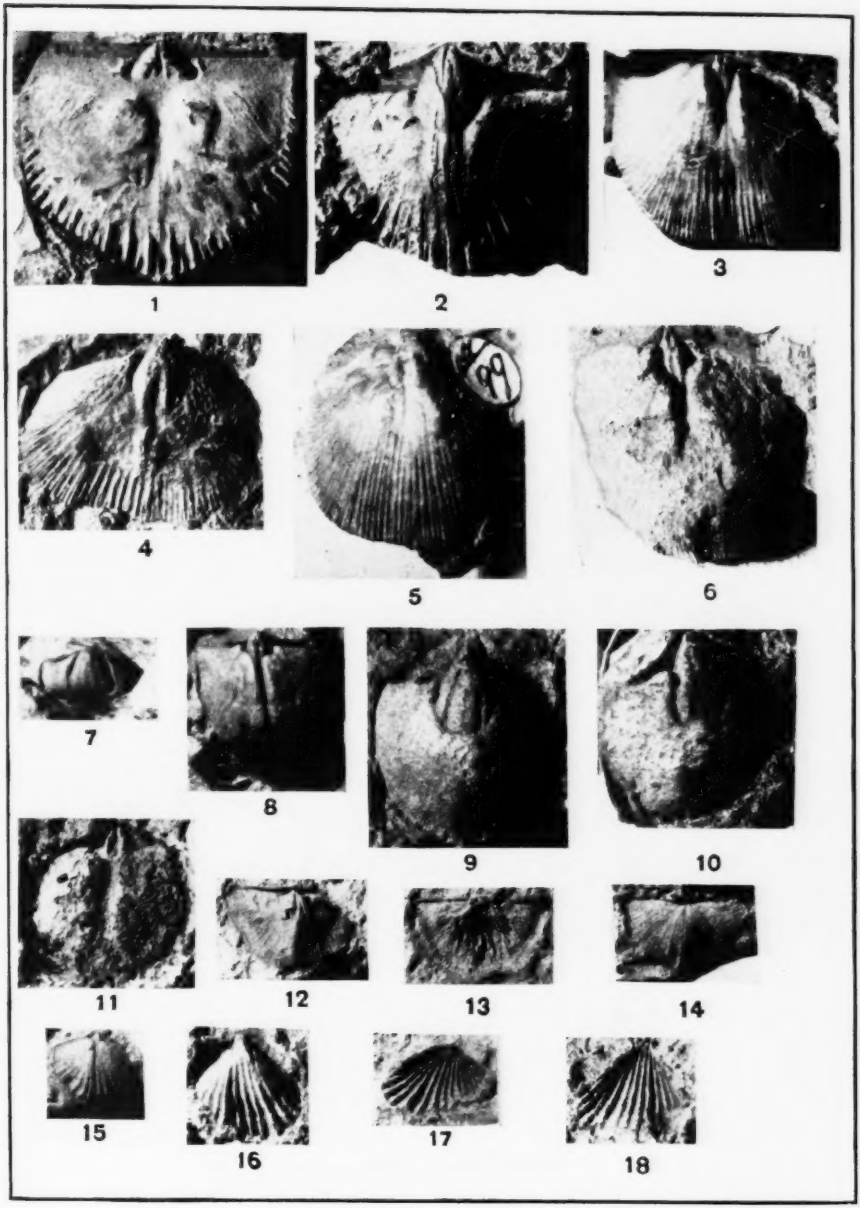
FIG. 9.—Internal mould of ventral valve (A11,100).
FIG. 10.—Internal mould of ventral valve (G.S.M. 75,255).
FIG. 11.—Internal mould of dorsal valve (G.S.M. 75,257a).

Sowerbyella antiqua var. *llandeiloensis* var. nov.

FIG. 12.—Internal mould of ventral valve (G.S.M. 75,268).
FIG. 13.—Internal mould of dorsal valve (G.S.M. 75,269).
FIG. 14.—External cast of dorsal valve (G.S.M. 75,270).

Rostricellula triangularis sp. nov.

FIG. 15.—Internal mould of dorsal valve (G.S.M. 75,231).
FIG. 16.—Internal mould of ventral valve (G.S.M. 75,230).
FIG. 17.—External cast of dorsal valve (G.S.M. 75,232b).
FIG. 18.—External cast of ventral valve (G.S.M. 75,232a).



NEW LOWER ORDOVICIAN BRACHIOPODS.

The Gare Loch Re-advance Moraine [1]

By J. G. C. Anderson

Abstract

Detailed drift mapping near the Gare Loch, Dumbartonshire, has confirmed that the loch was formerly occupied by a late valley glacier marking a re-advance contemporaneous with re-advances in the Loch Lomond and Upper Forth Valleys. The moraine of the Gare Loch glacier, which has been traced for some miles on both sides of the loch, locally rests on clays of the " 100-ft." sea and is overlain by " 25-ft." beach gravels.

Introduction

THE Gare Loch is one of the best known of the numerous arms of the sea which extend from the north side of the Firth of Clyde into the South-West Highlands. It branches from the Firth just west of Helensburgh, Dumbartonshire, and runs in a north-westerly direction for six miles. For the most part the Gare Loch penetrates Dalradian schistose grits and slates. Near its mouth, however, sandstones and conglomerates of Upper Old Red Sandstone age are present, brought against the Dalradian rocks by a north-easterly fault.

One of the most conspicuous features of the Gare Loch is Row Point, a narrow gravel headland projecting for half a mile from the eastern shore near the village of Row (Rhu). Row Point lies opposite another headland of similar type extending outwards from Rosneath on the western side of the Gare Loch. Between the two points the width of the loch is reduced at low tide to 200 yards, and the depth of the channel is about 30 feet compared with depths of nearly 100 feet not far to the north and south.

The earliest reference in geological literature to the headlands at Row and Rosneath appears to have been made by J. Anderson (1896, p. 198), who provides a map showing a glacier occupying the Gare Loch as far south as Rosneath. The author puts forward the view that the terminal moraine of this glacier is represented both by the gravel banks forming the points at Row and Rosneath and by raised beach deposits along the shores of the loch. In the case of the raised beaches he suggests that the action of the sea has destroyed the original morainic form.

Anderson's paper does not seem to have been given the attention it deserved, and until fairly recently it appears probable that most observers regarded the headlands in question as ordinary gravel spits formed solely by marine agencies. In 1936, however, McCallien (1936, p. 386) again suggested that Row Point marked the site of a moraine and gave a description of the section exposed on its north face.

[1] Published by permission of the Director, H.M. Geological Survey.

During 1946 and 1947 the present author re-mapped the district on the 6 in. scale in the course of a revision of Sheet 30 of the Geological Map. He not only found himself in full agreement with the previous workers already mentioned regarding the significance of Row Point, but was also able to trace the moraine on the hillside on both sides of the loch (Text-fig. 1).

Description

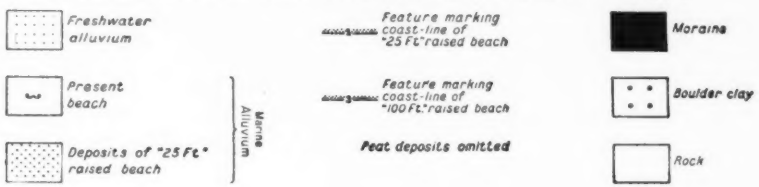
Row Point.—On the north-west side of Row Point wave action has exposed a section about 250 yards long and from 15 to 20 feet high, a description and sketch of which have already been given by McCallien (1936, Fig. 2). As the face is subject to minor landslips, the debris from which is periodically removed by storms, it shows changes from time to time in clarity and continuity. The thickness of the different beds also varies from point to point. A generalized section recorded by the writer in September, 1946, follows :—

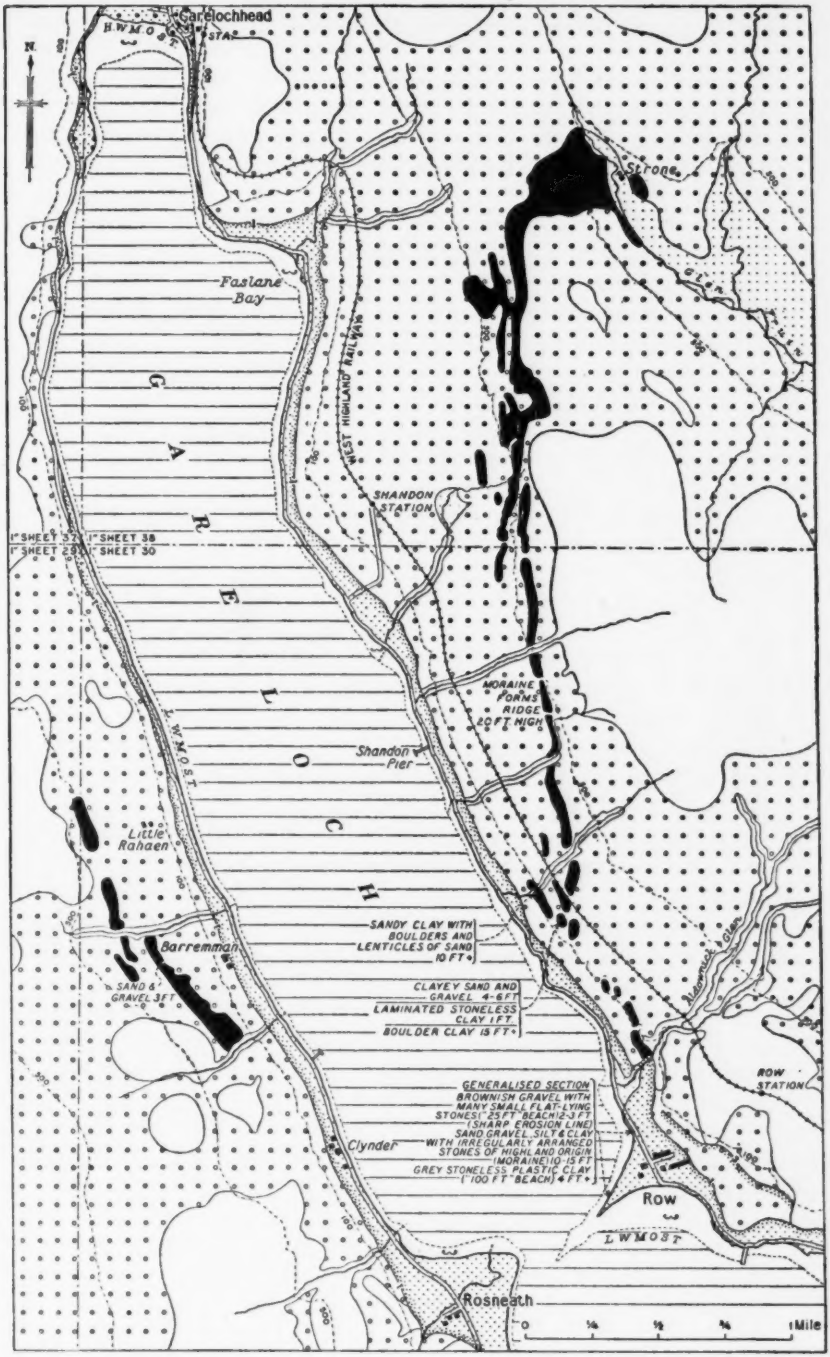
Brownish, well-bedded gravel with many small flat-lying stones.	2–3 ft.	" 25 ft." Raised Beach Deposit.
Sharp erosion line.		
Sand, gravel, silt, and clay, with irregularly arranged stones of Highland origin. (Base ill-defined owing to slipping.)	10–15 ft.	Moraine.
Grey, stoneless, plastic clay, with distorted bedding.	4 ft. +	" 100 ft." Raised Beach Deposit.

The morainic deposits are characterized by rapid lateral variation. In some places they appear unstratified ; in others they are well stratified and sometimes show current-bedding. The basal clay, which is finely laminated, is identical with that common in the " 100 ft. " beach deposits throughout much of the Clyde estuary. A small indeterminable shell-fragment was found by the author, and from a sample of the clay Mr. F. W. Anderson obtained ostracods (*Cytheropteron latissimum*), foraminifera, plant seeds, and beetle fragments.

East Side of Gare Loch.—Between Row Point and Aldownick Glen the moraine is hidden under " 25 ft. " raised beach deposits. A low feature, brought out by a slight but sharp rise on the main road near where it leaves the coast on the north side of the point, may mark

Text-fig. 1.—Map of Gare Loch Re-advance Moraine. (Opp.)




Garelochhead
H.W.M.O.S.T.
N
Strone
Faslane Bay
WEST HIGHLAND RAILWAY
G A R E L O C H H
SHANDON STATION
1" SHEET 37
1" SHEET 38
1" SHEET 29
1" SHEET 30
MORAINE FORMS RIDGE 20 FT HIGH
L.W.M.O.S.T.
Shandon Pier
Little Rahaen
Barremman
SAND & GRAVEL 3 FT.
SANDY CLAY WITH BOULDERS AND LENTICLES OF SAND 10 FT.
CLAYEY SAND AND GRAVEL 4-6 FT.
LAMINATED STONELESS CLAY 1 FT.
BOULDER CLAY 15 FT.
Pollochaig Glen
ROW STATION
GENERALISED SECTION
BROWNISH GRAVEL WITH MANY SMALL FLAT-LYING STONES 25 FT. BEACH (2-3 FT. (SHARP EROSION LINE)
SAND GRAVEL, SILT & CLAY WITH IRREGULARLY ARRANGED STONES OF HIGHLAND ORIGIN (MORAINE) 10-15 FT.
GREY STONELESS PLASTIC CLAY (100 FT. BEACH) 4 FT.
Clynder
Row
L.W.M.O.S.T.
Rosneath
0 ¼ ½ ¾ 1 Mile

the face of the moraine. On the south side of the stream in Aldownick Glen, 320 yards upstream from the main road, morainic deposits, consisting of 5 feet of clayey sand with numerous irregularly arranged boulders, rest on 15 feet of stiff light-grey boulder clay with many small stones.

Between Aldownick Glen and Croy (five-eighths of a mile S.S.E. of Shandon Pier, Text-fig. 1) the moraine is represented by a line of low discontinuous mounds on the slope between the main road and the West Highland railway. A section in a stream 225 yards from Croy shows :—

Clayey sand and gravel with irregularly arranged boulders.	4–6 ft.
Laminated stoneless clay	1 ft.
Yellowish-grey boulder clay . . .	15 ft. +

The topmost beds are definitely morainic in character, and the laminated clay, which lies about the 100 ft. level is probably part of the " 100 ft. " beach deposits.

In half a mile northwards from Croy the moraine, marked by low mounds and shelves in the hillside, rises from the 100 ft. to the 400 ft. level, on the hillside above Shandon Pier. For half a mile north of this point the moraine is particularly striking, as it forms a ridge about 50 feet across and from 10 feet to 20 feet high, broken only where breached by small streams. One of these streams, flowing into the Gare Loch south of Shandon Pier, is diverted along the outside of the moraine for some 300 yards.

East of Shandon station the moraine lies about 500 feet above sea-level and is marked by two distinct lines of low mounds. The more easterly and higher line tails out against a steep slope, but the more westerly continues northwards as a comparatively broad zone of highly irregular mounds and ridges situated between the 500 and 600 ft. contours.

The moraine, marked by mounds 10 feet to 15 feet high, which small excavations show to consist of clayey sand with abundant stones, reaches its highest point, about 650 feet, a mile east of Faslane Bay. It then turns eastwards into Upper Glen Fruin where it is represented by low mounds, overlying boulder clay, between the 450 and 500 ft. contours in the vicinity of Strone. It is not possible to trace the moraine beyond this point as there is no sign of its presence on smooth boulder clay slopes to the north of Strone.

Between the moraine and the Gare Loch the solid rocks are mostly mantled in boulder clay, forming comparatively smooth slopes, which contrast strongly with the moundy morainic zone. West of Faslane Bay, however, the hillside is slightly hummocky and the surface appears

in places sandy or loamy. A thin spread of morainic drift may therefore overlie the boulder clay in this area but it is not sufficiently well defined to be mapped. Thin morainic drift may also be present about half a mile S.S.E. of Shandon Station where the surface is slightly hummocky, and cuttings along a railway siding show sandy deposits overlying the boulder clay. It is difficult to be certain whether these sandy deposits are truly morainic or are simply hill-wash. In the same cutting fine-grained schistose grits and slates which normally dip S.E. at about 45 degrees are bent over near the surface into the vertical or even slightly overturned towards the S.E. This is almost certainly due to the drag of ice moving down the Gare Loch.

Along the shore of the loch the " 25 ft. " beach is marked by a continuous shelf sloping gently upwards to a well-marked feature, the base of which lies about 35 feet above O.D. It is of significance that the " 100 ft. " beach, well developed between Helensburgh and Row, comes to an end in line with Row Point and has not been detected further up the Gare Loch.

West Side of Gare Loch.—There can be little doubt that the point at Rosneath is of the same character as Row Point, although there are no sections which reveal its internal structure. For $1\frac{1}{4}$ miles to the north no trace of the moraine could be detected. The hillside immediately above this part of the loch is steep, and rock is either at the surface or is covered by only a few feet of boulder clay.

A wood, half a mile long, at about the 300 ft. level west of Barremman appears to have been planted on the moraine, as the surface is frequently loamy or sandy and shows many small stones ; sand and gravel up to 3 feet thick are exposed in drains. It is possible that morainic deposits have here been spread out on the slope by solifluxion. West of the northern end of the wood poorly developed mounds are seen at about the 400 ft. level. These are continued north of the Meikle Burn (flowing into the Gare Loch north of Barremman) by an interrupted line of low, but clearly defined, mounds, which finally come to an end west of Little Rahaen, at about 400 and 500 feet above O.D., a height roughly corresponding with that of the moraine on the opposite side of the loch.

Conclusions and Correlations

The writer is in full agreement with previous workers that Row Point is of morainic origin. From the Point the moraine has been traced by the author more or less continuously for a distance of 4 miles on the east side of the loch. On the west side it is not so strongly developed, nor so continuous, but it has nevertheless been followed for a distance of $2\frac{1}{2}$ miles. There can, moreover, be little doubt that the

moraine marks the limit of advance of a late valley glacier post-dating the " 100 ft. " beach deposits and pre-dating those of the " 25 ft. " beach. The Gare Loch re-advance must therefore have been contemporaneous with the Loch Lomond and Upper Forth readvances described by Simpson (1933, p. 633).

As the field work carried out by the author was confined to Sheet 30 and a small part of Sheet 38 it was not found possible to examine lochs and valleys farther to the west and north, but detailed study of the glacial deposits in these districts might well reveal evidence for the former presence of readvance glaciers of the same age.

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The Pediment Landform : Some Current Problems

By Lester King

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Abstract

The pediment is a widespread and fundamental landform adapted to and moulded by sheet-flow of surface water. The usually abrupt transition from hillslopes to pediments corresponds to a change in surface water flow from linear- to sheet-flow. A cut-rock surface is an essential feature, and where this is buried beneath a detrital mantle some climatic change is to be suspected.

FROM the time of their description by Kirk Bryan in 1922, pediments have appeared periodically in geological literature, generally under the guise of land-features of arid or semi-arid regions. They are, however, not absent from the landscapes of humid regions, and current research indicates that pediments are, indeed, the most widespread and possibly the most important of all land-forms.

Nowadays it is tolerably clear that pediments originate by the parallel retreat of hillslopes behind them. Within any given district whereof the rocks are sensibly homogeneous, the hillslopes often show a remarkably narrow range of declivity, though the hills may differ widely in size and stage of development. This could not be so if the hillslopes, once a stable angle of declivity was attained, had maintained that angle closely throughout their further development. Southern Rhodesia provides many admirable examples of this principle (King, 1949), which is best demonstrated in semi-arid environments. Where the bedrock is not subject to rapid weathering and is of high intrinsic strength, the hillslopes are steep and the contrast between hillslopes and pediment is abrupt (the inselberg landscape) (King, 1949B). Local weathering effects may produce even a nick or overhanging " inverted pediment ", but this is abnormal.

After the pediment has been generated by slope retreat, certain forces act upon it to produce the typical form, a sweeping curve of water erosion from the foot of the hillslope to a near-by stream or river. The modifications produced at this stage (termed pedimentation) are characteristic of sheet-flow on the part of surface water (King, 1949).

The development of landscapes by the twin processes of slope retreat and pedimentation (united as *pediplanation*) is the fundamental mode of landscape development since the Mesozoic, as is exhibited by the physiography of all the continents (King, 1949A). Pediments are limited in extent only by the texture of the drainage pattern, and in declivity only by the lapse of time available before the erosion cycle is distributed and by the potency of the agents of that cycle. But

even to the end, when pediplanation is extreme, pediments still retain a concavity, the concavity of water erosion, and any residuals still rise sharply from the pediment surface.

In all Africa (and with this, data from other continents agree), despite many references, not a single true peneplain exists. All the old-age surfaces—and there are many—are multi-concave pediplains with steep-sided residuals. Parallel scarp retreat and pedimentation have formed them. The South African high veld is a superb example of extreme pediplanation with virtually all its slopes concave. Davis's description of it (1906, pp. 377–480) " The surface has broad swells of very faint convexity between broad depressions of equally faint concavity . . ." is no more than imaginary. Even Mt. Monadnock, prototype of monadnocks, is concave in profile.

Without doubt, all the more ancient landscapes of the globe (Gobi, Africa, etc.) are pediplains and not peneplains (King, 1949A). Their surfaces are multi-concave, not multi-convex. Only when a new cycle causes weak incision of the streams do such plains show *convexity* as in the gently tilted terrains of the Eastern Transvaal around Standerton and Ermelo. Convexity alone is sufficient proof in old-age terrains of two-cycle topography ; and Walther Penck's concept of *endrumpf* and *primärrumpf* is valid. Examples can be quoted from every one of the continental masses, despite W. M. Davis's denial (1932, p. 421). Easily accessible examples for Southern Africa are : for *endrumpf*, the high veld of the Union of South Africa, or the middle and lower Sabi Valley of Southern Rhodesia ; and for *primärrumpf* the landscape west of the railway between Daisyfield and Gwelo, Southern Rhodesia, and many areas in the west of the Union and Bechuanaland.

So the pediment landform, it seems, is very important. It is the fundamental form to which most, if not all, subaerial landscapes tend to be reduced, the world over. This is different from the " Normal Cycle " which one learnt in College days ; but appeal to the world's landscapes leaves no room for doubt : pediplanation, and not peneplanation, provides the keys to the interpretation of continental landscapes.

Thus it has proved possible to map erosion surfaces of an age as great as Mesozoic, because without down-weathering such surfaces survive almost indefinitely (King, 1949, 1949A, 1949C) ; and beyond the seas, it is now feasible to correlate certain landscape cycles from continent to continent (King, 1949A). Peneplanation never did these things ; in fact, with emphasis on down-weathering of hills, it denied the possibility of them.

With pedimentation and pediplanation new weapons have come to the geomorphologist, but before he wields them too heartily it would be well to discover a little more of how they work. The rest of this

study will therefore be devoted to some inquiry into the mechanism of pedimentation.

Of recent years attention has been focused upon pediments as units of the South African landscape. The preponderance of pediments over all other landscape forms has been demonstrated (King, 1947, pp. xvii–xviii), and preliminary inquiry has been made into the mode of origin and development of the pediment form (Fair, 1947, 1948, 1948A ; King, 1949).

Fundamental is the subdivision of the landscape into hillslopes and pediments. These two forms together comprise virtually the whole of the erosional landscape of the African continent. Such clear subdivision over enormous areas, and on many different kinds of rocks, suggests that there is some essential difference in the type of erosional agencies operating on the two forms respectively.

The researches of Fair (1948) have indicated that parallel slope retreat is effected largely by the development of numerous small " gully-heads ". Thus water is dispersed upon hillslopes by thread-flow or linear-flow. But, as the angle of slope falls off, and under the heavy incidence of rainfall typical in Africa, thread-flow soon becomes incapable of removing the volume of precipitation : the threads join up into sheets of flowing water and a land-form is needed which can dispose of sheet-flow. *This land-form, adapted to, and moulded by, sheet-flow of water is the pediment.* It can dispose of the large volume of water produced by a thunderstorm of intensity 3 or 4 inches per hour more efficiently, more quickly, and with less damage to the landscape than any other topographic form : it is the answer to the thunderstorm and the cloudburst.

But pediments need not be confined to regions of rapid precipitation. The hydraulic principles involved apply under more equable regimes when saturation of soil is attained.

Let us examine these hydraulic principles.

Firstly, turbulence is much more generally associated with flow in confined channels than with laminar or sheet-flow, and hence the turbulence associated with the hillslope rills makes them powerful eroding agents and rapid retreat of the hillslopes results.

On the other hand, laminar or sheet-flow across the pediment takes place with a minimum of turbulence and erosion, so that the pediment form is stable and long-lived. Several other reasons conspire towards the same end. Spreading of water in sheets ensures the greatest possible thinness of flow (normally only a small fraction of an inch), and a consequent minimum of turbulence, for turbulence increases for a given velocity with increased depth of flow. Also, with the greater volume of water on pediments as compared with hillslopes (for the pediments must carry the hillslope water as well as their own) there is

greater opportunity for the upper layers of soil to be quickly saturated. When saturation is attained water tends to flow on water, in laminae, so that again turbulence is decreased and erosion minimized.

In the flow of water upon pediments there is thus a reciprocal advantage. A gentle, flat slope of great breadth favours the occurrence of viscous flow in laminae ; and a viscous sheet-flow causes a minimum of erosion and promotes the establishment of a semi-stabilized land-form of low declivity.

Despite the occurrence of vegetation, and especially scattered bushes upon pediments, turbulence seldom is generated thereby. Rather the depressed water surface of viscous flow is usually visible about such obstructions. Herein is a fruitful topic for research by soil conservationists.

Where, however, the sheet-flow is changed by obstruction or channelling into thread-flow, turbulence is immediately created, and the results are disastrous : soils which did not move under laminar flow are swept away, and dongas develop rapidly across the plane of the original pediment. King and Fair (1944) some years ago drew attention to the fact that dongas were typical not so much of steep hillslopes as of relatively flat pediments. In the change from viscous laminar flow to turbulent channellized flow lies the solution of that paradox. The wide, almost universal occurrence of pediments proves the long establishment of conditions appropriate to their formation ; and the fact that so many are scarred by recent dongas shows more clearly than anything else how much interference has been permitted with natural sheet-flow. Clearly, for control of soil erosion in pedimented landscapes, research is needed into the manner of sheet-flow and particularly into methods of preventing sheet-flow from deteriorating into thread-flow. So our gully-scarred pediments insist. None the less, it is interesting to note how many of the recognized, purely empirical methods for control of erosion, such as contour-ploughing and strip-cropping, are really practical applications of the basic principle.

If pediments are a result of sheet-flow, then they should appear best in regions where the *intensity* of precipitation is high, and this is indeed so ; but pediments may appear in any situation where thread- or linear-flow is inadequate to disperse surface water. Thus, towards the foot of slopes in humid climates, where rainfall is much less intense, linear-flow may prove, as the declivity diminishes, inadequate to dispose of the precipitation. This is especially so if the soil is already saturated, when there will be a tendency for " water to flow on water ". At the foot of all slopes, therefore, conditions exist which may lead to pediment formation, and it is significant that in these situations appear the " valley-plain side-strips " recorded by W. M. Davis and which we may class as narrow or incipient pediments.

The fact that the pediment form is governed more by the strenuous conditions of short periods of intense precipitation, rather than by the steadier, long-continued effects of drought or of mild precipitation, is in harmony with other geomorphological phenomena. River channels and shoreline features notoriously owe their formation more to the exaggerated effects of rare floods or storms than to long periods of normal action.

Reduction in the peak incidence of rainfall must produce conditions less favourable to sheet-flow in the landscape. Thus, under a reduced rainfall, or under a more evenly distributed rainfall, thread-flow may be favoured and dongas develop across a previously existing pediment. (The generation of such dongas will doubtless be aided by any reduction in the level of ground-water.)

A further point which has received little attention: the upper surface of existing pediments is often a surface of deposition. Sections displayed in the walls of dongas often reveal from six to ten feet of detritus (transported waste mantle) commonly coarse at the base or throughout. This thickness of mantle is far too great to be moved, even by the greatest floods, and must represent a phase of accumulation. For the mantle rests not upon progressively weathered bedrock but upon a cleanly cut eroded rock surface which, in most instances, is comparatively fresh. Striking, too, is the parallelism between this cut surface and the surface of the ground above, even over whole districts.

Unquestionably, the fundamental feature of the pediment form is the cut-rock surface, whether it is buried or not; but, as pediments must be reduced ever to lower angles of slope during their existence, the presence over wide areas of such a cover is to some extent anomalous. For the present, some result of climatic change may be suspected. If so the phenomenon will be useful for correlation. Cooke has already remarked how often Middle Stone Age tools are associated with a phase of donga-cutting in the South African landscape.

Conclusion

Pedimented landscapes consist essentially of hillslopes and of pediments. The transition from one to the other is usually abrupt, and corresponds generally to the change in surface water flow from linear-flow to sheet-flow with a corresponding change in character from turbulent to viscous flow. The change takes place relatively suddenly and hence its topographic expression is equally abrupt, separating topographic zones of steepness and low stability from zones of flatness and high stability. Scarps separating cyclic erosion surfaces usually remain juvenile though the topography above and below them is mature or old. The presence of soil upon the pediment also initially reduces

the surface flow by absorption, and, when saturated, produces a tendency for laminar flow of "water upon water" according to established hydraulic principles.

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Kyanite-Gneiss within a Thermal Aureole

By W. S. MacKenzie

(PLATE XII)

Abstract

This preliminary note records two discoveries in the Ross of Mull. Kyanite is considerably more widespread in the Moine rocks than previous investigations have indicated. Where the kyanite-gneiss enters the thermal aureole of the granite, large andalusite paramorphs are formed from kyanite.

THE rocks of the Ross of Mull, Argyllshire, which have been referred to the Moine Series, are bounded on the north-east by the Tertiary plateau lavas and on the west by the Ross of Mull granite. The area was investigated by Bosworth (1910). The present writer is chiefly interested in the development and paragenetic relationships of the three polymorphous forms of Al_2SiO_5—kyanite, andalusite and sillimanite—in the Ross of Mull. The wider geological implications are not within the writer's field of research.

Two separate occurrences of kyanite-gneiss have been described by Bosworth, the mineral being in each case associated with tourmaline. The first is, in Bosworth's words " within a belt of the Moine rocks about 80 yards wide and traceable along the strike for nearly half a mile. The best exposure of this belt is at its northern end, opposite to and about 400 feet south-west from the foot of Loch Assapol in the cliff of the 100 ft. raised beach ". It has now been established that this belt of kyanite-gneiss can be traced almost continuously for two miles along the dominant direction of strike, from Loch Assapol to Ardalanish Bay where it enters the aureole of the Ross of Mull granite as defined by the Geological Survey (Text-fig. 1). (The aureole has not been marked on Sheet 35 but its approximate location has been obtained by continuation of the line marked on Sheet 43.)

The kyanite-gneiss is easily recognizable in the field by the blue crystals of kyanite, averaging about an inch in length, which stand out on the weathered surface of the rock. As might be expected, the mineralogical changes which occur when the kyanite belt enters the aureole are most interesting. Here the gneiss is a beautiful coarsely crystalline rock in which most of the minerals are in a fresh condition (Pl. XII, fig. 1). The blue colour of the kyanite crystals becomes interspersed with pink where they have been transformed into andalusite and particularly fine examples of the association of these two minerals have been developed in quartz-rich segregations (Pl. XII, fig. 2). This transformation is easily seen in the field and the first occurrence of andalusite coincides with the outer limit of the thermal aureole as shown in the accompanying sketch-map.

The formation of andalusite from kyanite as a result of subsequent thermal metamorphism has been described by A. G. MacGregor (1928) from the Lochnagar area in Aberdeenshire and, through the kindness of Dr. MacGregor, the present writer has been able to examine his thin sections superficially. There are some aspects of this occurrence which are different from that of the Ross of Mull : the rock from Aberdeenshire is, in general, finer grained and the relicts of kyanite are relatively small ; while the distribution of andalusite in the Braemar area is not always clearly related to igneous phenomena.

The reverse change has been described by Tilley (1935) in the Carn Chuinneag area (Ross-shire), where kyanite has been developed after chiastolite as a result of the superposition of regional metamorphism on a thermal aureole.

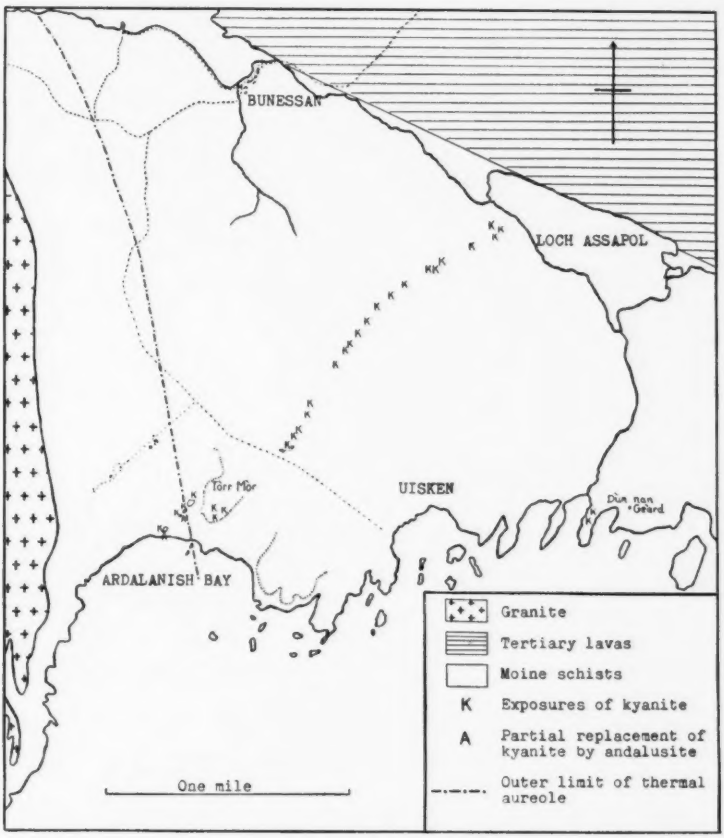
In the Loos-Hamra region of Sweden, von Eckermann (1936) has attributed the replacement of sillimanite by andalusite to thermal readjustment, on approaching a granitic intrusion. From the same area he has described the conversion of andalusite into kyanite as a result of intense shearing stress accompanying faulting of cordierite-andalusite schists.

Erdmannsdörffer (1928) has described two occurrences of the association of kyanite and andalusite. The first, from Lisenz (Tyrol), has been interpreted as kyanite formed by subsequent regional metamorphism of original andalusite, the complete transition from the andalusite to kyanite being seen in thin section. The other occurrence, from Val Calanca (Switzerland), consists of sub-parallel intergrowths of kyanite and andalusite in which the " c " crystallographic axis of the andalusite lies approximately in the (100) plane of kyanite.

In the case of the Ross of Mull occurrence, the andalusite paramorphs do not extinguish uniformly but consist of irregularly oriented grains ; this texture is doubtless due to the increase in specific volume accompanying the inversion. The orientation of several grains of andalusite and of the kyanite which they partly replace, was obtained by means of the Universal Stage and plotted stereographically. No simple crystallographic relationship was found to exist between the two minerals.

In general, the association of these two minerals in the same thin section is rare and the association is even more interesting on account of the fact that intergrowths of andalusite and prismatic sillimanite are found in the pelitic gneiss within the Ross of Mull aureole (Bosworth, 1910). It would be reasonable therefore to expect to find the association andalusite-sillimanite or even kyanite-andalusite-sillimanite where the kyanite band approaches nearer to the margin of the granite on the west side of Ardalanish Bay. So far the writer has been unable to trace the reappearance of this band in this locality.

According to Bosworth (1910) and Clough (1911) an outcrop of kyanite-gneiss occurs intimately associated with amphibolite at a locality on the shore approximately 280 yards west of Dùn nan Geàrd. The kyanite is very localized in development, but crystals can be seen in the field and average about half an inch in length. This rock is



TEXT-FIG. 1.—Sketch-map of part of the Ross of Mull showing the distribution of kyanite.

distinctive on account of the large porphyroblasts of garnet, measuring on an average three-quarters of an inch in diameter, and there is also an abundance of biotite. On field evidence this biotite- and kyanite-rich rock appears to be part of the massive garnetiferous amphibolite within which it occurs and into which it grades. Although both andalusite and sillimanite were detected by Flett, the present writer

has so far been unable to confirm the presence of either of these minerals.

From this brief survey it is clear that there is need of a detailed investigation of the occurrence and relationship of the polymorphous forms of Al_2SiO_5 in the Ross of Mull and this is being undertaken by the writer.

For help in preparing and checking this note in manuscript, the writer is indebted to Professor C. E. Tilley, Dr. H. I. Drever, Dr. E. F. Freundlich and Mr. R. Johnston.

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EXPLANATION OF PLATE

FIG. 1.—Kyanite-gneiss, Dùn Fuinn. × 20. Crossed nicols. The N.W. part of the field consists of a large twinned kyanite porphyroblast with inclusions of tourmaline, rutile and apatite. An andalusite paramorph after kyanite extends from the N.E. to the S.W. corner of the field and it can be seen to consist of elongated and irregularly oriented grains. The dark patch at its N.E. extremity, however, is kyanite with a peculiar "imbricate" structure.

FIG. 2.—Quartz-rich segregation in kyanite-gneiss, Dùn Fuinn. × 20. Ordinary light.

Andalusite enclosing small relicts of kyanite can be seen at the junction of two large kyanite crystals.

FIG. 1.

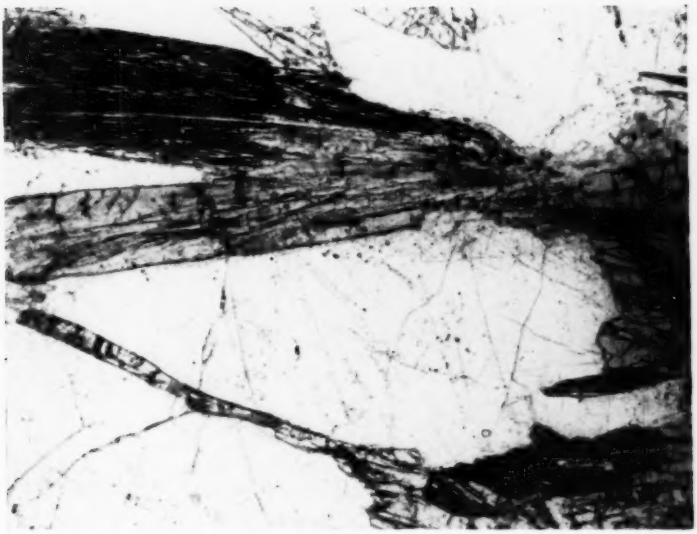

FIG. 2.

The Source of Some Erratics from North-Eastern Northamptonshire and adjacent parts of Huntingdonshire [1]

By P. A. Sabine

Abstract

A collection of erratics from the Boulder Clay and associated remanié drift of the Nene Valley includes distinctive sedimentary, igneous, pyroclastic, and metamorphic rocks. Localities are suggested from which these may have originated and it is concluded that the Upper Chalky Boulder Clay was brought by ice moving from a direction west of north.

DURING the primary 6 in. survey of New Series Sheet 171 (Kettering) and the adjacent parts of Sheet 172 (Ramsey), a suite of erratics was collected by J. E. Prentice and P. A. Sabine from the area lying to the east of the River Nene in north Northamptonshire and Huntingdonshire, not far from Oundle. The rocks outcropping in this area consist of a very gently dipping series of alternating limestones and clays comprising the Inferior and Great Oolite Series, Cornbrash and Oxford Clay. The limestones form a series of nearly flat plateaux bounded by gentle scarps. The best developed of these plateaux is that formed by the Cornbrash, from which the Oxford Clay has been extensively eroded to form steep slopes, capped by Boulder Clay, some distance back from the edge of the limestone. The Boulder Clay is a gritty grey clay containing abundant chalk both as fragments and as finely disseminated matter. Boulders are abundant, consisting mainly of quartzite of Bunter type, flint, and local rocks including Jurassic limestone and ironstone. Less abundant are boulders of brown sandstone, possibly from the Millstone Grit, and boulders of Carboniferous Limestone. Below the outcrop of the Boulder Clay similar boulders occur in a residual bouldery drift which blankets the slopes of the Oxford Clay, e.g. in the valley of the Billing Brook, south-west of Chesterton. Upon the Cornbrash and lower beds this drift forms a thin pebbly spread until eventually it merges with the river gravels and can no longer be distinguished.

Petrography of the Erratics

The present contribution deals with certain erratics which are so distinctive lithologically as to be easily recognized in the field and to be serviceable as indicator boulders. They have been collected from the Boulder Clay and from the associated remanié drift and include rocks of sedimentary, igneous, pyroclastic, and metamorphic types.

[1] Communicated with the permission of the Director of the Geological Survey and Museum.

Sedimentary Types.—Among those sliced, sedimentary rocks include a greywacke (E. 21241) [1] and a sandstone with tourmalinized cement (E. 21199). The latter is similar to rocks occurring in the Loweswater Flags of Murton Fell, Cumberland. One of the sliced specimens (E. 13244), described in the *Geological Survey Memoir*, " The Geology of the Whitehaven and Workington District " (Eastwood, 1928), compares reasonably well with this erratic, although it contains a somewhat greater quantity of tourmaline ; granulitized quartz forms a larger number of grains ; iron ore is present in smaller quantity, and the tourmaline is more commonly in stout prisms. The greywacke (E. 21241) is a chloritic feldspathic grit with a considerable quantity of carbonate, including calcite and dolomite. The groundmass and quartz and feldspar grains are replaced by the carbonate which often shows well-developed crystal faces. The feldspar includes albite and oligoclase, partially sericitized and perhaps prehnitized. Fragments of shale and grains of iron ore are abundant. This rock resembles the Lower Palaeozoic greywackes of the Southern Uplands, where the calcareous nature of some greywackes has already been remarked upon by Professor W. Q. Kennedy and Professor H. H. Read (1936), and Dr. Malcolm Macgregor (1937). The former authors drew attention to the fact that the carbonate replaced the cement and the clastic quartz and feldspar grains, but in the rocks they described the carbonate did not form well-developed crystals in the cement.

Igneous and Pyroclastic Types.—Igneous rocks include a quartz-dolerite (E. 21242), a porphyrite-breccia (E. 21240), and a granophyric porphyrite (E. 21248). The last-named is composed of phenocrysts of plagioclase set in a holocrystalline groundmass commonly showing granophyric texture and resembles rocks occurring in North Wales, for example the granophyric porphyrite of the Tanycraig Quarry, about ten miles south-south-west of Caernarvon, near Clynnog. The porphyrite-breccia (E. 21240) is an epidotic rock very similar to breccias or agglomerates of Charnwood Forest and compares well with a specimen in the Survey Collection (E. 19171) from the Forest Rock Quarry. The quartz-dolerite (E. 21242), which is of Whin Sill type, is a fine-grained rock consisting of a network of labradorite laths with prisms and stout laths of augite, enstatite, and pigeonite. Alkali feldspar is present, moulded on the labradorite laths, and quartz is interstitial. Iron ore present encloses feldspar and augite.

Pyroclastic rocks are represented by an andesitic tuff (E. 21243) composed mainly of fragments of volcanic rocks together with feldspar, quartz, iron ore, and rare biotite set in a very fine-grained holocrystalline groundmass of feldspar laths cemented by chlorite. This rock may be

[1] Numbers in brackets refer to the English Series of sliced rocks in the Geological Survey collection.

compared with types from the Borrowdale Volcanic Series, for example with the Geological Survey specimen E. 13018 from the north-eastern corner of 1 in. New Series Sheet 37 (Gosforth), to which it bears a fairly close resemblance.

Metamorphic Types.—The collection of erratics also includes some interesting metamorphic rocks. There are two calc-silicate rocks, one a banded epidote, amphibole, garnet, calcic feldspar-granulite (E. 21197) resembling those found in the aureole of the Dartmoor Granite, and the other a scapolite-bearing quartz-hornblende-granulite (E. 21255). Scapolite rocks are not common in Britain but occur in various parts of the Scottish Highlands and in Devon. The erratic resembles the Scottish rather than the Devon types, which are represented in the Survey collection by specimens from Pullabrook and from Walkhampton, south-west of Princetown. These contain a higher proportion of fine-grained material and are more finely foliated than the Scottish rocks.

As metamorphic rocks should also be classed four erratics which are typical of the tourmaline-bearing rocks of the south-west of England. Two of these may be called schorl rock, one (E. 21200) consisting of sheaves of tourmaline up to 6 mm. in length set in a base of interlocking quartz grains, and the other (E. 21254) composed of abundant small radial aggregates of tourmaline set among granular quartz. The other two rocks (E. 21198, 21247) are tourmalinized breccias. These rocks may have been derived from the Midlands Bunter beds, where similar rocks have been recorded by Waller, Bonney, Matley, Dr. J. Phemister, Mr. H. G. Dines, and others. In his researches into the sources of the Bunter pebbles, Matley submitted two tourmaline-bearing specimens from near Birmingham to H. H. Thomas, who reported that they consisted of a schorlaceous breccia and a schorlaceous granite and that it was " hard to assign any other source to these pebbles than the West of England, for in that region alone can the types be matched with any degree of closeness " (Matley, 1914).

More recently Mr. H. G. Dines has recorded (in Richardson, 1946) tourmaline-bearing pebbles from the drift of the Witney District, and these were examined by Dr. J. Phemister, together with specimens collected by Mr. Dines from the Bunter Pebble Beds of South Staffordshire (Phemister, 1936). Regarding the source of these rocks, Dr. Phemister stated that the Staffordshire pebbles were similar to the Witney specimens, some of which strongly resembled the quartz-tourmaline-schist of Roche.

Other erratics, which have insufficiently diagnostic features to suggest any particular locality, include a quartzose sandstone (E. 21202), a fine-grained silica rock (E. 21201), an amygdaloidal trachyte (E. 21249), containing vesicles up to 2 mm. in length filled with granular

quartz, a sheared epidiorite (E. 21251), a hornblende-gneiss (E. 21253), and a garnetiferous hornblende-schist (E. 21257).

Unsliced rocks include one specimen of brown micaceous sandstone, a muscovite pegmatite, a leucocratic microgranite, a foliated quartzite, three specimens of tourmalinized breccia, a dark grey siliceous rock containing veins and blebs of quartz, a muscovite-quartz-schist, and a granular quartz rock having a vitreous lustre and with garnet-rich inclusions containing muscovite and tourmaline.

Directions of Ice-Movements

The drifts of the Nene area suggest that there has been more than one glaciation resulting in a Lower Boulder Clay widely found south of Kettering, overlain by Mid-Glacial gravels followed by Chalky Boulder Clay. The freedom of the Lower Boulder Clay from chalk and flint and the presence of Jurassic and Bunter erratics suggest a derivation from the north along a route lying wholly west of the Lincolnshire Wolds (Hollingworth and Taylor, 1946).

The ice from which the Chalky Boulder Clay has resulted came down the valleys of the Trent and the Witham, receiving additions from the Pennine Ice and from the North Sea Ice. That the chalk of the Chalky Boulder Clay has come largely from Lincolnshire is claimed by Harmer (1928) to be shown by the constant presence and great abundance in the Boulder Clay of grey flint and hard chalk characteristic of that area.

To the east of the Pennines, the present outcrop of the Bunter Pebble Beds occupies a tract of country stretching north from a little east of Nottingham to the vicinity of Doncaster. It therefore seems possible that the abundant Bunter Pebbles of the region here described have been brought from the Trent Basin by ice moving south-eastwards.

The three erratics suggestive of a Scottish, Lake District, and Whin Sill origin respectively may also have been carried by this ice. Harmer, however, suggests (1928, p. 124) that igneous erratics in the Nene-Ouse basin are derived from beds of Contorted Drift age formerly existing in the Fenland, having come originally from the North Sea.

The tourmaline-bearing rocks and the calc-silicate rock resembling types from the Dartmoor aureole may also have been derived from the Trias by south-easterly moving ice, but until the geography of Triassic time is known more definitely the derivation of these rocks must be regarded with considerable caution.

The erratic of granophyric porphyrite may have been brought east by ice from North Wales and thence by the ice which deposited pre-Chalky Boulder Clay. It is not, however, impossible that this erratic

was derived from the Bunter Pebble Beds deposited in the Midlands in Lower Triassic times.

Evidence for the route by whch the Charnwood rock has reached

TEXT-FIG. 1.—Sketch map showing localities mentioned.

the area is provided by the general distribution of Charnwood erratics, which are found most commonly in the Leicester area to which they have been transported by glaciers moving south-eastwards from the Derwent and Dove valleys. It would appear likely that the erratic now

recorded was brought by this route and was then carried across the Jurassic outcrop by easterly moving ice.

Mr. D. F. W. Baden-Powell has recently suggested (1948A, B) that Upper Chalky Boulder Clay was deposited in eastern England by ice moving in a direction from east of north. In view, however, of the presence in the Upper Chalky Boulder Clay of the Oundle region of abundant Bunter pebbles and of the other erratics described above, the writer is of the opinion that the ice responsible for this boulder clay must have come from distinctly west of north.

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CORRESPONDENCE

PALAEOGEOGRAPHY OF THE MIDLANDS

SIR,—As pointed out in your review of my recent book, *The Palaeogeography of the Midlands*, I there suggested that " the Downtonian and Dittonian are pre-Devonian in age ". I write to beg the indulgence of your pages to make a public confession that I must have had a mental aberration when I wrote this. It is regrettable that the memory of bygone discussions with Mr. Wickham King and carelessness in verifying my statement about the correlation of the beds containing " *Pteraspis dunensis* and other forms with the lowest part of the marine Devonian of the Continent " (I had in mind the Siegenian) should have led me to make this egregious mistake which, I fear, may add to the confusion that has existed over the Siluro-Devonian boundary.

Should a second edition of my book be called for, I shall adopt a classification which would put the whole of the Downtonian into the Devonian, a view which I supported in my *Physiographical Evolution of Britain.*

L. J. WILLS.

THE UNIVERSITY,
EDGBASTON,
BIRMINGHAM, 15.

14th July, 1949.

SALT TECTONICS AND A POSSIBLE IGNEOUS ANALOGY

SIR,—In regions where groups of incompetent rock are interbedded with competent strata, and where large differences of density exist between the two types, crustal disturbance gives rise to rather distinctive tectonic phenomena.

Where the incompetent rock is salt, the structures present are commonly associated under the name of "salt tectonics" and include disharmonic folding, diapiric structures, thrusts, and salt plugs. Salt plugs are frequently large sub-cylindrical masses of salt which either emerge at or approach the surface, having forced their way up by gravity differential. The penetration at the surface is commonly marked by a comparatively sharp, upturned junction without any great disturbance of the surface strata for more than a short distance away from the plug periphery.

When recently considering the probable crustal fore-shortening which appears to have occurred between South Wales and the Brest Peninsula of France, due to the great movements at the end of Carboniferous time, it appeared that this fore-shortening might be in the neighbourhood of 150 miles. The general type of folding rather suggested an analogy with usual salt tectonics of a country like Iran, though on a much larger scale.

It might be possible to consider the Cornish and Devonian granite masses as due to dynamic forces familiar to those giving rise to salt plugs, in which the rise of the masses has been mainly due to the gravity difference existing between the liquid acid magma, and that of the more rigid overburden. Such a viewpoint would suggest a density difference between the overburden and the mean density of the rising magma of something in the neighbourhood of 0·3, with the magma being comparatively light in its molten state when containing its water vapour and gases. To what extent this magma contained sediments melted by depression to great depths during the fore-shortening is not, of course, clear, but this would not be in conflict with the point of view outlined.

With so great a fore-shortening the crustal rocks must suffer very considerable elevation or depression, and as no great elevation is suggested, depression must have taken place, but an estimate of the amount requires very much more knowledge than is at present available as to the position of possible major thrusts developed during these movements. The rather small scale puckering across the Devon peninsula rather suggests the presence of a major thrust underlying these rocks, allowing considerable movement to take place without large scale disturbance of the upper thrust sheet.

While aware of the formidable difficulties in attempting to tidy up such a hypothesis as outlined above, we feel that it might be placed before those interested in such problems for their consideration.

M. W. STRONG.

EAKRING.

7th April, 1949.

THE ORIGIN OF RED SANDSTONES AND CONGLOMERATES

SIR,—I am grateful to Professor Eliot Blackwelder for the information he gave in the March–April number of this magazine about extensive alluvial fans; but on p. 325 of my paper (1948), after citing instances, I said: "These examples of extensive fans show that such fans may have entered into the formation of the New Red Sandstone, but the absence of radial structure makes it doubtful." Owing to unavoidable delay my paper did not appear until long after the completion of the field-work on which it was based, and until after the XVIII International Geological Congress. Between two excursions when I had the privilege of demonstrating the coast-sections of New Red Sandstone in South Devon to our guests, I was able to do more field-work and subsequently deposited with the Geological Survey a chart showing the dips from Broad Sands in the south to the River Exe, also some specimens of boulders with sections, and specimens of structures I found on

Watcombe beach during the first excursion. Of these last Dr. C. J. Stubblefield permits me to quote him as saying that the meniscus-arrangement of rock-particles suggests matter that has passed through the body of an animal, probably an annelid. They are doubtless the annelid tracks mentioned by Ussher and occur in deep red calcareous sandstone about three feet above the Watcombe Clay. Ussher, for some reason I cannot understand, included this rock with the Watcombe Clay, but it is clearly New Red Sandstone. The largest of these specimens I saw measured 14 by 1 inches. Publications show that even larger earthworms are known, but these structures are more likely to have been caused by marine or lacustrine worms on a shore ; and their position close to the Watcombe Clay, which I am now sure is weathered Devonian sedimentary rock, and their apparent absence higher up as far north as Dawlish, suggest that their disappearance was due to the amount of iron in the water.

My difficulty about accepting the alluvial fan origin of the New Red Sandstone of South Devon is that I cannot see convincing evidence of radial dips which ought to be visible in the long, clear coast-sections. Perhaps someone else may succeed where I have failed.

J. B. SCRIVENOR.

68 CHAUCER ROAD,
BEDFORD.

19th June, 1949.

AUTHIGENIC FELSPAR IN FULLER'S EARTH

SIR,—Dr. W. W. Black, in his letter [1] on an Occurrence of Authigenic Felspar and Quartz in Yoredale Limestones, states that he is aware of only one previous record of authigenic felspars in Britain—those described by Reynolds.[2] Another, however, can be mentioned. Newton [3] said that the clean, flaky felspar crystals found in the Jurassic fuller's earth of Combe Hay, near Bath, and the Cretaceous earths of Nutfield and Woburn Sands were almost certainly authigenic. Not only were the optical characters measured, but samples were separated and analysed. Both Nutfield and Combe Hay material, which were similar, suggested the composition of anorthoclase. Brammall and Leech [4] said later that the felspars in the Nutfield fuller's earths were demonstrably auth genic but found that the felspar crop (7·2 per cent in one of the commercial samples) was heterogeneous and the composition variable.

Not only, therefore, have we here records of authigenic felspars in fairly large percentage, but descriptions of authigenic sphene, zircon, and apatite in the Cretaceous earths, and zinc blende, zircon, and apatite in the Jurassic earth.

In all probability these fuller's earths were chemical deposits, like limestone ; under these conditions one may expect minerals beside the main ones to crystallize out. Glauconitic rocks would be expected to yield further examples. The form of the authigenic crystals is of interest in showing some characteristics of incipient crystallization as well as others of well-defined crystallinity.

ROBERT H. S. ROBERTSON.

1 BOTANIC CRESCENT,
GLASGOW, N.W.

28th May, 1949.

[1] BLACK, W. W., 1949. *Geol. Mag.*, lxxxvi, 129.

[2] REYNOLDS, D. L., 1929. Some new occurrences of authigenic potash felspar. *Geol. Mag.*, lxvi, 390.

[3] NEWTON, E. F., 1937. The petrography of some English fuller's earths and the rocks associated with them. *Proc. Geol. Assoc.*, xlviii, 175–197.

[4] BRAMMALL, A., and LEECH, J. G. C., 1940. Montmorillonite in fuller's earth, Nutfield, Surrey. *Geol. Mag.*, lxxvii, 102–112.

REVISED NOMENCLATURE FOR YORKSHIRE ESTUARINE SERIES

SIR,—With the publication of Dr. Hemingway's welcome revision of the nomenclature of the Yorkshire Estuarine Series (*Geol. Mag.*, lxxxvi, 67–71), attention is focused on the inadequacy of a three-fold terminology to describe a four-fold natural division. There is, however, a danger of confusion in that Dr. Hemingway's proposal introduces different stratigraphical limits to his " Middle Deltaic Series " to those previously universally applied to the " Middle Estuarine Series ". The only way of avoiding ambiguity is to apply place-names to all four of the deltaic divisions of the series and accordingly such names are proposed below. At the same time the writer suggests certain other minor modifications, such as the substitution of the word " Beds " for Hemingway's " Sub-Series ".

Fox-Strangways	Hemingway	Sylvester-Bradley (here proposed)
Upper Estuarine Series	Upper Deltaic Series	Scalby Beds
Scarborough or Grey Limestone Series	Grey Limestone Series	Scarborough Beds
Middle Estuarine Series	Gristhorpe Sub-Series (= upper part of Middle Deltaic Series)	Gristhorpe Beds
Millepore Series	Millepore Series	Millepore Series
Upper part of Lower Estuarine Series	Sycarham Sub-Series (= lower part of Middle Deltaic Series)	Sycarham Beds
Eller Beck Bed	Eller Beck Bed	Eller Beck Bed
Lower part of Lower Estuarine Series	Lower Deltaic Series	Hayburn Beds

The two new terms proposed (Scalby Beds and Hayburn Beds) are named after two famous localities for plants in the respective strata.

P. C. SYLVESTER-BRADLEY.

DEPARTMENT OF GEOLOGY,
ST. GEORGE'S SQUARE,
SHEFFIELD, 1.

25th May, 1949.

AN INTERNATIONAL SECRETARIAT FOR SEDIMENTARY PETROLOGY

SIR,—Sedimentary petrologists from twelve different countries held an informal meeting in London last year after the XVIIIth International Geological Congress. As a first step towards the formation of some kind of international organization, it was resolved to set up immediately an International Secretariat for Sedimentary Petrology. Dr. D. J. Doeglas was unanimously elected international secretary.

The Secretariat intends first of all (1) to compile and maintain an up-to-date list of active workers in the subject (addresses, fields, publications, etc.) ;

(2) to compile and maintain a comprehensive bibliography of the subject; and (3) to act as a general bureau for the supply of information, facilitation of contacts between workers, etc.

Sedimentary petrologists are invited to send personal details to :—

Dr. D. J. DOEGLAS,
Landbouwhogeschool,
Laboratorium voor Mineralogie en Geologie,
WAGENINGEN,
Netherlands

and to make use of the services offered.

A full report of the meeting referred to may be found in *Journ. Sed. Pet.*, 1949, xix, 43–7.

P. ALLEN.

SEDGWICK MUSEUM,
CAMBRIDGE.

REVIEWS

A TEXTBOOK OF GEOMORPHOLOGY. By P. G. WORCESTER. vii + 584, with 385 text-figures. Van Nostrand Co., Inc. Second Edition, 1948. Price 30*s*.

Few important changes distinguish this volume from the 1939 edition, which has been found one of the more useful elementary geomorphological texts. While primarily designed for the "arts" student as a cultural introduction to the surface of the earth, it serves the geologist with a growing arsenal of geomorphological jargon. Forgetting his own transgressions, he may marvel at the tendency for everyday terms to achieve a technical status, and so graduate from a purely descriptive use to head a paragraph of frequently superfluous definition. However, the author claims to give precise definitions, and succeeds in incorporating these in an attractive book.

W. B. H.

INTRODUCTION TO HISTORICAL GEOLOGY. By RAYMOND C. MOORE. McGraw-Hill : London, New York, Toronto, 1949. 8vo, vii + 582, illustrated. Price 30*s*.

Professor Moore aims here at the presentation of earth-history to those having no previous acquaintance with the subject. To achieve his object, he has brought together both an admirable collection of maps, diagrams, photographs, and correlation tables, and a clear, straightforward command of the English language.

In a work intended primarily for the American student, it is not surprising to find much of the stratigraphy falling outside the scope of British elementary courses while hardly reaching the detail needed by the more advanced. Nevertheless, the generous use of photographs, and particularly air-photographs, should appeal to the beginner as showing geology in the grand manner, and advanced students will find here a valuable means of setting detailed successions in a general survey.

From the palaeontologist's viewpoint the main interest lies in the excellent restorations of life-assemblages at various periods, but the short morphological section at the end of the book seems of less value. One would prefer to see, in a mainly stratigraphic work, some indication of outstanding problems and controversies, both to avoid in the reader the impression of a finished work, and to stimulate the application of fresh minds to old discussions.

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